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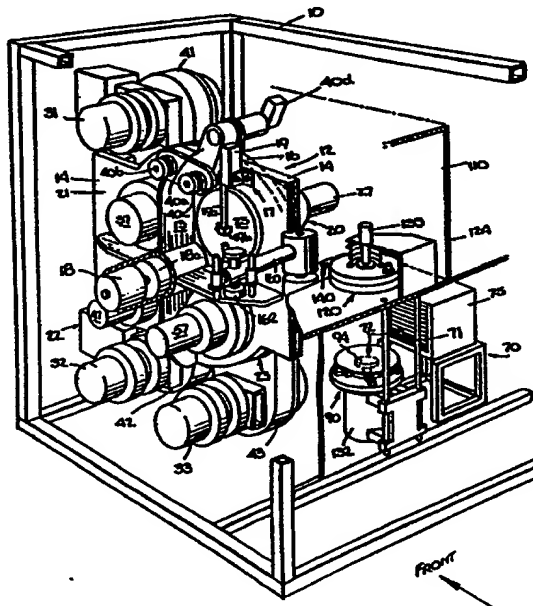
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54 Method and apparatus for handling and processing wafer like materials.

57 The apparatus comprises a plenum or main chamber which is divided into two chamber halves. A rotatable index plate is disposed in the chamber. An article to be processed is inserted into a load-lock station formed in the main chamber. After the article is inserted into the load-lock, it is engaged by an article holding device mounted in a position of the rotatable index plate. The index plate is then rotated to a second station, at which a process can be performed upon the substrate, for example, an etching or sputtering process. The process is performed in a processing chamber which is fully isolated from the main chamber and other processing chambers. After rotation by one position, a processed substrate is removed from the load-lock and a new substrate inserted into the load-lock for processing. After a process step is carried out on a substrate, the index plate is again rotated to the next station where another process or removal through the load-lock may be performed.



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METHOD AND APPARATUS FOR HANDLING
AND PROCESSING WAFER-LIKE MATERIALS

CROSS REFERENCE TO RELATED APPLICATIONS

This application is related to the following co-pending applications assigned to the assignee of this application:

- Serial No. _____, filed _____, entitled METHOD AND APPARATUS FOR HANDLING AND PROCESSING WAFER-LIKE MATERIALS;
Serial No. _____, filed _____, entitled IMPROVED CATHODE AND TARGET DESIGN FOR A VACUUM SPUTTERING APPARATUS;
Serial No. _____, filed _____, entitled APPARATUS FOR IMPROVING THE UNIFORMITY OF ION BOMBARDMENT IN A MAGNETRON SPUTTERING SYSTEM.

BACKGROUND OF THE INVENTION

The present invention relates to a method and apparatus for handling and processing wafer-like materials. In particular, the invention relates to a method and apparatus for handling and processing thin wafers, such as semiconductor substrates. The apparatus of the present invention can be used in systems for such purposes as etching of semiconductor wafer substrates and sputtering of deposits on such substrates.

Known designs for wafer processing machines allow wafers to be processed in vacuum environments. Generally, it is often necessary to perform sequentially more than one process on a substrate. For example, it may be necessary, after the wafer is introduced into the vacuum environment, to etch the wafer for preparing a surface for subsequent process steps. The next step may be the sputtering of a first metallic layer on the substrate and a further sputtering deposition step or steps may then follow. In each case, different gases may be introduced into the chamber for the different sputtering steps and different cathode target materials are used, depending on

1 the material to be deposited onto the substrate. Accordingly,
2 different gaseous and plasma conditions are present for the
3 different process steps. Generally, the prior art devices
4 cannot allow simultaneous processing by different processes
5 using different gaseous atmospheres of more than one wafer at a
6 time, because once wafers are introduced into the vacuum
7 chamber, only that particular process using that particular gas
8 can be performed on the wafers in the chamber. If more than
9 one process is carried out simultaneously on different wafers
10 using these apparatus, cross contamination of the vapors and
11 gases from the different processes may occur. Accordingly, it
12 is not possible in these prior art arrangements to process more
13 than one wafer at a time if different processes using different
14 gases are to be performed upon the wafers. Thus, for example,
15 in these priorart machines which have a plurality of
16 processing stations, if it is desired to operate with, for
17 example, a first gas on a first of the wafers and a second gas
18 on a second wafer, such would not be possible simultaneously.
19 Instead, the entire vacuum chamber would have to be purged of
20 the first gas and the second gas introduced before the second
21 wafer could be processed. Additionally, if a process step is
22 to be performed on only some, but not all, of the wafers in the
23 chamber, because all wafers are exposed to the same
24 environment, there is the possibility of contamination of those
25 wafers which are not being processed.

26 Furthermore, it is also important that the wafers be
27 processed without transfer of the wafer between different
28 handling mechanisms once in the vacuum chamber. Generally, the
29 wafers to be processed in apparatus of the present invention
30 are fragile, and to avoid particulate formation or breakage, it

1 is preferable to avoid transfer of the wafer between different
2 transfer mechanisms.

3 Additionally, in wafer processing machinery,
4 especially machinery employing sputtering devices, it is
5 necessary to change cathodes and targets of the sputtering
6 devices, for example, to replace a target which has been
7 substantially used. The cathodes in sputtering equipment
8 generally include means for providing electromagnetic fields
9 around the target of a particular orientation and a target of
0 the material to be sputtered which is biased at high voltages
1 with respect to the support structure and the substrate upon
2 which the deposits are made. This causes the material of the
3 target to vaporize into a plasma and be deposited upon the
4 substrate. Where it is desired simultaneously to process a
5 plurality of substrates in different gaseous environments, it
6 is convenient to be able to replace only that particular target
7 which requires replacement without disturbing the controlled
8 environments in other process chambers in which the other
9 substrates are disposed.

0 SUMMARY OF THE INVENTION

1 Accordingly, it is an object of the present invention
2 to provide a wafer processing machine which allows simultaneous
3 processing of a plurality of wafer-like articles under
4 different environmental conditions.

5 It is furthermore an object of the present invention
6 to provide a processing apparatus for wafer-like articles which
7 eliminates possibilities of cross contamination of the articles
8 being processed.

9 It is yet another object of the present invention to
0 provide an apparatus for processing wafer-like articles in a

1 vacuum environment.

2 It is yet a further object of the present invention.
3 to provide an apparatus for processing wafer-like articles
4 having a main vacuum chamber used for transferring the article
5 between isolatable process chambers wherein the process steps
6 are carried out.

7 It is furthermore an object of the present invention
8 to provide a processing apparatus for wafer-like articles which
9 eliminates particulate formation or breakage of the articles by
10 preventing transfer of the article, once in the controlled
11 vacuum environment, between different transfer mechanisms.

12 It is yet another object of the invention to provide
13 a processing apparatus for wafer-like articles which insures
14 optimum cleanliness of the articles being processed.

15 It is still yet a further object of the present
16 invention to provide a processing apparatus for wafer-like
17 articles wherein, when necessary to replace that part of the
18 apparatus which requires replacement, for example, a cathode
19 target, it is not necessary to shut down the entire machine or
20 to disturb the controlled environments in other parts of the
21 apparatus which do not require the replacement of a particular
22 part.

23 It is yet still a further object of the invention to
24 provide a processing apparatus for wafer-like articles having
25 the ability to allow articles to be processed in parallel and
26 wherein an article can be subjected to a selected one of a
27 plurality of processes.

28 The above and other objects are achieved according to
29 one aspect of the present invention by apparatus for
30 transporting a wafer-like article and subjecting the article to

1 at least one process step comprising means defining a first
2 chamber maintained substantially continuously at a vacuum or
3 pressure level, aperture means in the first chamber through
4 which an article to be subjected to the process step can be
5 introduced into the first chamber, means in the first chamber
6 for receiving and holding the article, means for moving the
7 article held by the receiving and holding means substantially
8 in a plane of movement to a position in the first chamber
9 adjacent where the process step is to be performed on the
10 article, movable means for isolating the second chamber from
11 communication with the first chamber while the process step is
12 performed on the article and for thereafter opening the second
13 chamber to the first chamber so that the second chamber is in
14 communication with the first chamber after the article has been
15 subjected to the process step, the receiving and holding means
16 remaining in contact with the article during the performance of
17 the process step, and means for removing the article from the
18 first chamber after the article has been subjected to the
19 process step.

20 In the preferred embodiment, the moving means
21 comprises rotatable plate means disposed in the plane of
22 movement and the means for removing the article comprises the
23 aperture means through which the article is also inserted into
24 the first chamber.

25 In a preferred embodiment, the receiving and holding
26 means comprises first means coupled to the plate means and
27 defining an inner open area, first resilient means coupling the
28 plate means and the first means, second means disposed in the
29 inner open area and coupled to the first means, the second
30 means defining a further area contained within the inner open

1 area for receiving the article, and second resilient means
2 coupling the second means to the first means.

3 According to the invention, the first means comprises
4 sealing surfaces on first and second surfaces thereof, and the
5 movable means comprises closure means movable toward and away
6 from one of the first and second surfaces and having a surface
7 for engaging in sealing relationship with the one of the first
8 and second surfaces of the first means, the means defining the
9 first chamber having a further surface for engaging in sealing
10 relationship with the other of the first and second surfaces of
11 the first means, the first resilient means allowing the closure
12 means to bias the other of the first and second surfaces of the
13 first means against the further surface of the means defining
14 the first chamber in a direction substantially perpendicular to
15 the plane of the plate means, whereby when the closure means
16 engages the one of the first and second surfaces and the other
17 of the first and second surfaces engage the further surface,
18 the second chamber is sealed from the first chamber.
19 Preferably, the article comprises a circular wafer, the first
20 means comprises first ring-shaped member means, the second
21 means comprises second ring-shaped member means and the first
22 and second resilient means comprise arcuate flat spring means.

23 Preferably, the closure means comprises cup-shaped
24 means with the surface for engaging in sealing relationship
25 comprising a rim of the cup-shaped means. Additionally, it is
26 preferable that the second means is removably coupled to the
27 first means by detent means so that it can be removed from the
28 first means when necessary, for example, for cleaning purposes.

29 The second ring-shaped means preferably includes an
30 edge along at least a part of an inner periphery thereof

1 extending into the further area against which peripheral
2 portions of the article can be received, and clamping means are
3 provided comprising means disposed on the second means movable
4 so that a portion thereof can be moved into a position
5 extending over at least a part of the further area defined by
6 the inside of the second means. Preferably the clamping means
7 is rotatably movable over at least a part of the further area
8 defined by the inside of the second means.

9 In a preferred embodiment, the rotatable plate means
10 comprises disk means rotatably movable in the first chamber
11 about a central axis, the disk means comprising means for
12 holding a plurality of the receiving and holding means, the
13 means defining the first chamber comprising means for
14 supporting a plurality of work stations at positions spaced
15 equi-angularly and equi-distantly about the central axis.

16 Preferably, the apparatus according to the invention
17 also includes article handling means for inserting the article
18 to be processed into the first chamber and for removing the
19 article after processing from the first chamber. According to
20 a preferred embodiment, the article handling means comprises
21 means for retrieving an article from a carrier member and for
22 placing the article on a movable support member, first arm
23 means for receiving the article from the movable support
24 member, and second arm means for receiving the article from the
25 first arm means and for inserting the article into the aperture
26 means in the first chamber. The first and second arm means
27 preferably are bi-directional so that they also are used to
28 remove a processed article from the chamber and return it to
29 the carrier member. Preferably, the first and second arm means
30 are disposed in a third chamber isolated from the first chamber

1 and the external environment. The third chamber includes entry
2 means for receiving an article from the movable support means,
3 and the movable support means comprises means for engaging in
4 sealing relationship with a sealing surface arranged around the
5 entry means when an article is inserted through the entry
6 means. The entry means further comprises movable sealing means
7 disposed in the third chamber for forming a fourth chamber in
8 the third chamber isolated from the third chamber.

9 In a preferred embodiment, the first arm means is
10 movable in an arcuate path and the movable sealing means is
11 movable so as to open the third chamber to the fourth chamber
12 when the pressures in the third and fourth chambers have been
13 substantially equalized. Preferably, the first and second arm
14 means comprise vacuum chuck means for engaging the article.
15 The second arm means is preferably pivotable in the first plane
16 or a plane parallel to the first plane so that the end thereof
17 defines an arcuate path for receiving the article at a defined
18 position along the path and further is rotatable about a
19 longitudinal extent of the second arm means. In a preferred
20 embodiment, the second arm means comprises first and second
21 vacuum chuck means, one of the vacuum chuck means adapted for
22 receiving an article from the first arm means in the first
23 plane or a plane parallel to the first plane and the other
24 adapted for transferring an article to the first arm means in
25 the first plane or a plane parallel to the first plane. The
26 second arm means is adapted for rotating the article about the
27 longitudinal extent of the second arm means so that the article
28 can be inserted into the aperture means in the first chamber
29 from the second arm means or received through the aperture
30 means in the first chamber for transfer to the first arm means.

1 Also, in the preferred embodiment, the second arm means
2 includes locking and unlocking means for engaging with the
3 clamping means to secure the article in the receiving and
4 holding means or allow its removal.

5 According to a further aspect of the invention, an
6 apparatus for holding a wafer-like article in a movable support
7 means and for allowing movement transverse to the support means
8 is provided comprising first means coupled to the support means
9 and defining a first inner open area, first resilient means
10 coupling the support means and the first means, second means
11 disposed in the inner open area and coupled to the first means,
12 the second means defining a second inner open area contained
13 within the first area for receiving the article, second
14 resilient means coupling the second means to the first means,
15 and means disposed on the second means for securing the article
16 disposed in the second area to the second means.

17 Preferably, according to this further aspect of the
18 invention, the apparatus for holding a wafer-like article is
19 disposed in a first chamber and a second chamber is in
20 communication with the first chamber and the first means
21 defines sealing surfaces on first and second surfaces thereof,
22 one of the first and second surfaces being engageable in
23 sealing relationship with a surface of a wall means of the
24 first chamber and the other surface being engageable in sealing
25 relationship with movable closure means for isolating the
26 second chamber from the first chamber while a process step is
27 performed on the article in the second chamber, the closure
28 means comprising means movable toward and away from the article
29 and having a further surface for engaging in sealing
30 relationship with the other surface of the first means, the

1 first resilient means allowing the closure means to bias the
2 one of the first and second surfaces of the first means against
3 the surface of the wall means in a direction substantially
4 perpendicular to the plane of the wall means when the closure
5 means moves towards and engages the other surface of the first
6 means, the second chamber being isolated from the first chamber
7 when the further surface of the closure means engages the other
8 surface of the first means and the one surface of the first
9 means engages with the surface of the wall means.

10 Preferably, according to this further aspect of the
11 invention, the first means comprises first ring-shaped member
12 means and the second means comprises second ring-shaped member
13 means, the first and second ring-shaped member means being
14 disposed concentrically. The first and second resilient means
15 preferably comprise flat arcuate spring means.

16 According to this further aspect of the invention,
17 the apparatus further comprises backing means coupled to the
18 closure means and disposed in an area defined by the inside of
19 the closure means for coming into close proximity with a
20 surface of the article. The second resilient means comprises
21 means for allowing the article to move substantially
22 perpendicularly to a plane in which the first means is disposed
23 when the backing means comes into close proximity with the
24 article.

25 According to yet a further aspect of the present
26 invention, apparatus for transporting a wafer-like article
27 between first and second locations is provided comprising
28 carrier means at the first location for supporting a plurality
29 of the articles, means for retrieving an article from the
30 carrier means and for placing the article on a movable support

1 means, the movable support means comprising means for
2 transferring the article to a first intermediate position,
3 first arm means movable in a first plane for receiving the
4 article from said movable support means at the first
5 intermediate position, and second arm means movable in the
6 first plane or a plane parallel thereto for receiving the
7 article from the first arm means at a second intermediate
8 position and for delivering the article to the second location.

9 According to this yet further aspect of the present
10 invention, the first and second arm means are disposed in
11 chamber means isolated from the external environment, the first
12 location being in the external environment and the second
13 location being in communication with the environment in the
14 chamber means. The chamber means preferably includes entry
15 means for receiving an article from the movable support means,
16 the movable support means comprising means for engaging in
17 sealing relationship with a sealing surface arranged around the
18 entry means when an article is inserted through the entry means
19 by the movable support means.

20 The entry means preferably comprises movable sealing
21 means disposed in the chamber means for defining a further
22 chamber means between the movable sealing means and the movable
23 support means when the movable support means engages with the
24 sealing surface surrounding the entry means, thereby isolating
25 the further chamber means from the chamber means.

26 According to this yet further aspect of the
27 invention, in a preferred embodiment, the first arm means is
28 movable in an arcuate path in a first plane and the movable
29 sealing means is movable so as to open the chamber means to the
30 further chamber means when the pressure in the chamber means

1 and further chamber means have substantially equalized, thereby
2 allowing access by the first arm means to the article.
3 Preferably, the first arm means comprises vacuum chuck means
4 for engaging the article and the second arm means comprises
5 means pivotable in the first plane or a plane parallel to the
6 first plane and defining an arcuate path for receiving the
7 article at the first intermediate position along the path and
8 further is rotatable about a longitudinal extent of the second
9 arm means. The second arm means preferably comprises first and
10 second vacuum chuck means disposed at an end of the second arm
11 means. One of the vacuum chuck means receives an article from
12 the first arm means and transfers the article to the second
13 location, which may be a load-lock of a vacuum chamber. The
14 other vacuum chuck means receives an article from the vacuum
15 chamber and transfers it to the first arm means. The second
16 arm means rotates the articles about its longitudinal extent so
17 that one device can be used for simultaneously holding two
18 articles, one of which may be a processed article and the other
19 yet unprocessed.

20 According to yet still another aspect of the present
21 invention, an apparatus adapted for moving a wafer-like article
22 between first and second locations is provided comprising bi-
23 directional longitudinally extending arm means having an end
24 movable in a first plane along a path for receiving the article
25 at the first location along the path and for transferring the
26 article to the second location and for receiving an article at
27 the second location along the path and transferring the article
28 to the first location, at least two engaging means disposed at
29 an end of the arm means, the first and second engaging means
30 being rotatable about the longitudinally extending arm means

1 between the first plane and any of a plurality of further
2 planes, whereby the article can be transferred between the
3 first and second locations by a combination of movement in the
4 first plane and rotation about the longitudinally extending arm
5 means. Preferably, the engaging means each comprise vacuum
6 chuck means.

7 Preferably, the apparatus includes a carrier means
8 for holding a plurality of articles disposed adjacent the first
9 location and the article is subjected to a process step at the
10 second location and either one of the first and second vacuum
11 chuck means engages an article at the first location to be
12 processed at the second location and the other vacuum chuck
13 means engages an article which has been processed at the second
14 location and returns the article to the first location.

15 Preferably, the second location comprises a vacuum chamber
16 having an entry means defined by a load-lock door, and the
17 apparatus further comprises means for opening the door and
18 means in the chamber for holding an article to be processed in
19 the chamber, the holding means including means for clamping the
20 article thereto, the longitudinally extending arm means further
21 comprising means for actuating the clamping means. The
22 actuating means preferably comprises means disposed adjacent
23 the first and second vacuum chuck means and extending
24 perpendicularly to the longitudinally extending arm means for
25 engaging the clamping means.

26 Preferably, the holding means comprises a plurality
27 of clamping means and the longitudinally extending arm means
28 includes a plurality of actuating means for engaging
29 corresponding ones of the clamping means. Additionally, in a
30 preferred embodiment, the clamping means comprises rotatable

1 means for clamping an article between a first surface and an
2 extension of the clamping means, the clamping means comprising
3 keyway means, the actuating means comprising key means for
4 engaging with said keyway means, said key means being rotatable
5 in two directions so as to secure the article between the
6 extension of the clamping means and the first surface in one
7 direction and allow the removal of the article by disengaging
8 the extension of the clamping means from the article in the
9 other direction.

10 Although the invention relates to apparatus for
11 processing wafer-like articles in a vacuum atmosphere, it is to
12 be understood that the invention could also be applied at
13 pressures above atmospheric.

14 The above and other objects of the present invention
15 are also achieved by methods for transporting wafer-like
16 articles and subjecting the article to a process step and for
17 handling wafer-like articles as will be explained in greater
18 detail below.

19 BRIEF DESCRIPTION OF THE DRAWINGS

20 The invention will be described in greater detail in
21 the following detailed description with reference to the
22 drawings, in which:

23 FIG. 1 is an overall cut-away perspective view of the
24 apparatus according to the invention;

25 FIG. 2 is a left side partially sectional view of the
26 apparatus of FIG. 1;

27 FIG. 3 is a front sectional view of the apparatus of
28 FIG. 1;

29 FIG. 3A is a schematic diagram of the apparatus
30 according to the invention;

1 FIG. 4 is a more detailed front sectional view of
2 part of the apparatus of FIG. 1, and in particular, that part
3 of the apparatus which transfers unprocessed and processed
4 wafers from or to holding cassettes;

5 FIG. 5 is a top sectional view of that part of the
6 apparatus shown in FIG. 4;

7 FIG. 6 shows that part of the apparatus shown in FIG.
8 4 and illustrates some of the steps of wafer handling before
9 the wafer is introduced into a controlled environment of the
0 apparatus;

1 FIG. 7 shows the same view as FIG. 6 but shows
2 additional steps of wafer handling and insertion of the wafer
3 into a controlled environment of the apparatus according to the
4 invention;

5 FIGS. 8 and 9 show further top sectional views of
6 portions of the apparatus shown in FIGS. 4, 5, 6, and 7, and,
7 in particular, those portions of the apparatus and the steps
8 performed thereby directed to centering the wafer on a lifting
9 table and aligning an indexing mark disposed on the perimeter
0 of the wafer on the lifting table;

1 FIGS. 10 and 11 are sectional views showing parts of
2 the apparatus for transferring a wafer into and out of a
3 controlled environment chamber, and different steps performed
4 by such apparatus;

5 FIG. 12 shows a top view of a portion of the
6 apparatus for handling the wafer in the controlled environment
7 prior to or after processing of the wafer in the main chamber
8 volume;

9 FIG. 13 is a side sectional view of a portion of the
0 apparatus shown in FIG. 1, and in particular that portion of

1 the apparatus which relates to handling of the wafer in a
2 controlled environment of the apparatus according to the
3 invention;

4 FIGS. 14 and 15 show top partially sectional views of
5 the apparatus according to the invention illustrating steps in
6 handling of wafers in the controlled environment before or
7 after processing in the main processing apparatus proper;

8 FIGS. 15A and 15B show schematically the steps
9 involved in transferring a wafer to and from the wafer
10 processing apparatus proper;

11 FIG. 16 is a top view of the apparatus according to
12 the invention showing the main processing apparatus in its
13 opened condition;

14 FIG. 17 is a horizontal sectional top view through
15 the main processing apparatus of the invention taken through
16 section lines 17-17 of FIG. 2;

17 FIG. 18 is the same view as FIG. 17 but shows the
18 apparatus during a different step in the processing of a wafer;

19 FIG. 19 is a more detailed vertical sectional view of
20 a portion of the apparatus shown in FIG. 16 taken through
21 section lines 19-19 of FIG. 2;

22 FIGS. 20 and 21 show partial sectional views of
23 portions of the apparatus for transferring a wafer to and from
24 the main processing portion of the apparatus;

25 FIG. 22 is a detailed sectional view through a
26 portion of the main processing apparatus showing one processing
27 station according to the apparatus of the invention taken
28 through section lines 22-22 of FIG. 17;

29 FIG. 23 is a sectional view like that of FIG. 22
30 showing a different step in the processing of a wafer;

1 FIG. 24 is a front view of the means for holding a
2 wafer in a rotatable index plate of the main processing
3 apparatus of the invention;

4 FIG. 25 is a right side view of the apparatus
5 according to the invention;

6 FIG. 26 is a cut away right side view showing the
7 interior of the main processing apparatus according to the
8 invention; and

9 FIG. 27 is a rear view of the apparatus according to
10 the invention.

11 DETAILED DESCRIPTION

12 With reference now to the drawings, FIG. 1 shows a
13 perspective view of the apparatus according to the invention.
14 The front of the apparatus is considered to point to the right.
15 The apparatus comprises, generally, a frame 10 to which is
16 mounted a chamber 12, the chamber comprising two approximate
17 half sections 14 and 16. The chamber includes a rotatable
18 index plate 15, shown in greater detail in FIG. 26, which is
19 driven by a motor 18 through a sealing member 18a, which may
20 comprise a ferrofluidic sealing member. Each of the chamber
21 halves 14 and 16 are reinforced by reinforcing structures 13
22 and 13a, respectively. See FIG. 25. Chamber 12 halves 14 and
23 16 define a main plenum area 12a, shown in greater detail in
24 FIG. 26. Attached to each of the half sections 14 and 16 of
25 chamber 12 and disposed at equal angular intervals about the
26 center of chamber 12 are the respective portions of four work
27 stations 20, 21, 22 and 23. Station 20 comprises a load-lock
28 station for the entry and removal of processed or unprocessed
29 articles and stations 21, 22 and 23 comprise processing
30 stations wherein various processing steps, such as etching and

1 sputtering, may be carried out. In each work station, a
2 different step may be carried out upon a substrate held by the
3 rotatable index plate 15. Different processes may be
4 simultaneously performed on different substrates at the
5 different stations. In particular, station 20, which comprises
6 the load-lock station, allows substrates to be inserted into or
7 removed from the chamber 12 via a load-lock door 25 actuated by
8 associated door operating mechanism 19, to be explained in
9 greater detail later. Station 21 comprises a station wherein,
10 for example, the substrate may be cleaned or etched to prepare
11 it for further processing in stations 22 and 23, which may, for
12 example, comprise sputtering stations wherein metallic layers
13 are deposited on the substrate. Once a substrate has been
14 rotated in the direction shown by arrow 17 through stations 20
15 to 23, it is then rotated further to complete a cycle of
16 rotation to station 20, where the processed substrate is then
17 removed through load-lock door 25. The apparatus allows four
18 substrates to be disposed within the machine at any one time,
19 and three different processes may be performed at stations 21,
20 22 and 23 on three different substrates simultaneously.
21 Although four work stations are shown in the illustrated
22 embodiment, a lesser or greater number of work stations could
23 be provided by suitable modification of the apparatus.
24 The apparatus further includes a number of vacuum
25 pumps 31, 32, 33 and 40d, which may be cryogenic vacuum pumps,
26 for example, for providing the proper final vacuum levels in
27 each of the volumes of the processing stations 21, 22 and 23
28 and load-lock station 20, respectively. As will be explained
29 later, the apparatus of the invention allows the work station
30 volumes to be isolated from the main chamber volume 12a during

1 processing. Vacuum pumps 31, 32, 33 and 40d are coupled to the
2 respective stations by respective manifold members 41, 42, 43
3 and 40a. Before cryogenic pumps 31, 32, 33 and 40d are
4 activated, separate mechanical vacuum pumps connected to
5 suitable fittings 33a, 33b, 33c, and 33d are activated to
6 evacuate the respective chambers to a level close to the
7 desired vacuum level. See FIG. 25. Cryogenic pumps 31, 32, 33
8 and 40d then are activated to bring the vacuum down to the
9 desired levels. As shown in FIG. 25, fittings 33a, 33b and 33c
10 include suitable valve members 33e, 33f and 33g, respectively,
11 for disconnecting the mechanical vacuum sources from the
12 respective processing chambers 21, 22 and 23, respectively.

13 Each of stations 20, 21, 22 and 23 includes a first
14 section mounted on chamber half 14 and a second opposing
15 portion mounted on chamber half 16. This is shown most clearly
16 when viewed in conjunction with the top views of FIGS. 14 and
17 15, in the side views of FIGS. 2 and 26 and in the rear view of
18 FIG. 27. As shown in FIGS. 14 and 15, chamber half 14 includes
19 the load-lock door 25 at station 20, shown opened in FIG. 15
20 and closed in FIG. 14. The rear portion 16 of chamber 12 at
21 station 20 includes a front-plane device 27, the purpose of
22 which will be explained in greater detail below. At station
23 21, which, in the illustrated embodiment, is an etching
24 station, but may be a sputtering station, e.g., a back-plane
25 device 37 is attached to chamber half 14, and chamber half 16
26 has attached thereto manifold 41 and pump 31, which overlaps
27 the top of the chamber 12. Back-plane device 37 is similar to
28 front-plane device 27. At station 22, which may comprise a
29 sputtering station, a further back-plane device 47 is provided,
30 which may be disposed directly below the back-plane device 37.

1 This can be seen most clearly in FIGS. 1 and 2. The chamber
2 portion 16 as shown in FIG. 1 and FIG. 25, has mounted thereto
3 manifold 42 and pump 32, which extends below the chamber 12,
4 and which cannot be seen in FIG. 14. At station 23, which also
5 may be a sputtering station like station 22, chamber half 14
6 comprises a further back-plane device 57 and chamber portion 16
7 has mounted thereto manifold 43 and associated vacuum pump 33,
8 as shown in FIG. 1 and FIG. 25. Again, vacuum pump 33 is
9 disposed below the chamber 12 via the manifold 43. The two
10 chamber halves 14 and 16 are hinged together at 425 and a
11 locking mechanism, e.g., a screw fastener, is provided at 427.
12 See FIG. 25. At least one seal 426 is provided, e.g., O-ring
13 seals as shown in FIG. 26 for sealing the two chamber halves
14 together. FIG. 16 shows the two chamber halves in the opened
15 position. As shown, the various vacuum pumps and manifolds
16 open together with chamber half 16. Also, as shown in FIG. 18
17 and 27, each of the manifolds define a door which is hinged at
18 380, allowing access to the interior of the work station
19 without requiring opening of the main chamber 12.

20 A manifold 40a is attached to chamber half 14.
21 Manifold 40a allows vacuum from a main cryogenic vacuum pump
22 40d to be supplied to main chamber volume or plenum 12a and to
23 load-lock station 20, as necessary. Before pump 40d is
24 activated, a mechanical vacuum pump (not shown) is utilized to
25 bring the vacuum down in the plenum 12a or the load lock 20 to
26 a specified vacuum level close to the desired final level. A
27 fitting 33d is provided for this purpose. See FIG. 25. Pump
28 40d then is used to provide the final desired vacuum level. As
29 will be explained later, manifold 40a includes a valve 40b
30 which allows communication with main volume 12a, and valve 40c

1 which allows communication with the volume defined by the
2 load-lock station 20.

3 Although not shown in the drawings suitable power
4 supplies for biasing the cathode assemblies of the processing
5 stations and the substrates are also provided. Furthermore,
6 R.F. power supplies may also be provided behind the back-plane
7 devices 37, 47, and 57 for improving step coverage desposition
8 on the substrates.

9 As shown in the drawing figures, the apparatus
10 includes a wafer receiving section, indicated generally at 70,
11 a wafer alignment, centering and lift means 90, a controlled
12 environment chamber 110 having an intermediate load-lock
13 indicated generally at 120, a transfer arm 140 disposed in
14 chamber 110 for receiving and delivering a wafer from or to the
15 intermediate load-lock 120, and for transferring a wafer to or
16 from a load-lock arm 160, which transfers a wafer, whether
17 processed or unprocessed, to or from the main load-lock station
18 20 of chamber 12. Receiving station 70 includes a cassette 75
19 holding a plurality of wafers to be processed and/or wafers
20 which have already been processed by the apparatus of the
invention. A pick and place mechanism 80 transfer wafers
between cassette 75 and alignment, centering and lift means 90.
See FIGS. 2, 3 and 4. Two cassettes 75 and 76 may also be
used. See FIG. 4. As indicated, mechanisms 80, 90, 120, 140
and 160 are bi-directional, i.e., unprocessed wafers from
section 70 are transferred to chamber 12 by these mechanisms
and processed wafers are returned to section 70 by the same
mechanisms.

21 FIG. 3A is a schematic representation illustrating
22 the overall operation of the apparatus according to the present

1 invention. Substrates to be processed are supplied from one of
2 two cassettes 75 or 76 into the controlled environment 110 via
3 intermediate load-lock 120. The substrate is then transferred
4 into load-lock 20. A sealing member, for example, load-lock
5 door 25, isolates load-lock 20 from the controlled environment.
6 A valve 20a is utilized to vent the load-lock to the controlled
7 environment so that the load-lock door 25 can be opened to the
8 controlled environment 110 to allow the substrate to be
9 received in the load-lock 20. A mechanical pump (not shown)
10 and cryogenic pump 40d are utilized to evacuate the load-lock
11 20 via suitable valves including valve 40c, once load-lock door
12 25 is closed. A sealing member A, to be described in greater
13 detail below, seals the load-lock 20 from the plenum 12a, and
14 opens the plenum 12 to the load-lock once the load-lock has
15 been evacuated to the vacuum level existing in the plenum 12a.

16 As will be explained in greater detail below, the
17 plenum 12a, defined by chamber 12, is utilized to transfer the
18 articles to be processed from one processing chamber to
19 another. The processing chambers are shown at 21, 22 and 23.
20 The plenum 12a itself, however, is not utilized to perform
21 process steps, such as sputtering or etching. Rather, the
22 substrates are transported through the plenum and transferred
23 to at least one of the processing chambers, where the process
24 step is performed. In accordance with the invention, an
25 article to be processed need not be processed serially, as the
26 apparatus of the present invention allows an article to skip a
27 particular process chamber, for example. Assuming that the
28 article is to be processed in all process chambers, however,
29 the article is isolated from plenum 12a via sealing member B
30 and then supplied to process chamber 21. Pump 31 (and

1 associated mechanical vacuum pump) is utilized to evacuate the
2 process chamber 21 and a valve 21a provides process gas to the
3 process chamber 21. If further processing of the article is to
4 occur after processing in process chamber 21, the article may
5 be transferred to process chamber 22 through a sealing member
6 C, as shown. Pump 32 (and associated mechanical vacuum pump)
7 is utilized to evacuate process chamber 22 and process gas is
8 supplied to the process chamber 22 via valve 22a. If further
9 processing is to occur, the article may be transferred to
0 process chamber 23 through a sealing member D. A pump 33 (and
1 associated mechanical vacuum pump) is utilized to evacuate
2 process chamber 23 and process gas is provided to the chamber
3 23 via valve 23a. In the illustrated embodiment, three process
4 chambers are shown, although more or fewer process chambers
5 could be provided. After the article has been processed in
6 process chamber 23, it is again supplied back to the load-lock
7 20 via sealing member A. The article is then returned via
8 sealing means 25 to the controlled environment 110 and returned
9 to the cassettes 75 and 76.

0 Accordingly, the apparatus shown schematically in
1 FIG. 3A allows isolation of each process chamber 21, 22 and 23
2 from the other process chambers and also from the main plenum
3 12a. This prevents cross-contamination between processes being
4 performed in the different process chambers. Furthermore, the
5 apparatus shown allows essentially random access to the
6 different process chambers. Therefore, it is not necessary
7 that the article to be processed enter each process chamber.
8 Rather, the article to be processed can skip a process chamber
9 if that particular process is not to be performed on the
0 article. Additionally, the process to be performed in a

1 particular process chamber can be changed without affecting the
2 other process chambers, because of the isolation provided by
3 seals B, C and D which isolate each process chamber from the
4 others and the plenum 12a.

5 Furthermore, each process chamber 21, 22 and 23 is
6 essentially independent of the other process chambers, having
7 its own pumps, valves, gas inlets and processing means, so that
8 if one processing chamber ceases to function for some reason,
9 the other chambers are not affected. The gas inlets to each
10 process chamber are shown in FIG. 25 at 21a, 22a and 23a.

11 The structure of sealing members A, B, C and D will
12 be described in greater detail below, and forms an important
13 part of the invention. In the embodiment shown in the
14 drawings, sealing members A, B, C and D comprise sealing ring
15 members and resilient spring means which hold the article in
16 position during processing and also provide the necessary
17 motion and sealing action between the process chamber and the
18 plenum 12a. Although separate sealing members A, B, C and D
19 are shown in FIG. 3A, in an actual embodiment of the device,
20 the same sealing member is used to seal the different process
21 chambers once a substrate enters the plenum 12a, as the sealing
22 members perform not only a sealing function but also hold the
23 substrate in position during its movement in the plenum 12a.
24 More than one substrate, can, of course, be processed in
25 chamber 12 at one time, and accordingly, a plurality of sealing
26 members, one of which is associated with a respective process
27 chamber at a particular point in time, may be provided. This
28 will be explained in greater detail below.

29 The operation of the invention will now be described
30 in greater detail. With particular reference to FIGS. 3 and 4,

1 the apparatus of the present invention may include one cassette
2 75 or two cassettes 75 and 76 holding a plurality of stacked
3 wafers 72. Although the cassettes are shown to be
4 substantially horizontal in the drawings, they may have a
5 slight inclination from the horizontal so that the open ends of
6 the cassettes, shown in FIGS. 1 and 3 and identified with
7 reference numeral 71, are slightly raised from closed side 73.
8 In this way, sliding of the wafers in the cassettes 75 or 76 so
9 that they fall out of the open ends 71 is prevented. Cassettes
10 75 and 76 are mounted on frames 77 and 78, respectively. A
11 pick and place mechanism 80, which is movable in both X and Y
12 axes, shown in FIG. 3 and more clearly in FIG. 4, is provided
13 for retrieving unprocessed wafers from the cassettes and for
14 inserting processed wafers into the cassettes. Pick and place
15 mechanism 80 is driven by a motor 81 and a suitable linkage,
16 for example, along tracks 82. Pick and place mechanism 80
17 includes a movable arm 83 having suitable grasping mechanisms,
18 e.g., vacuum chucks 84 and 86, disposed at ends of the arm.
19 This is shown more clearly in FIGS. 4 and 5. Arm 83, as shown
20 in FIG. 5, is fastened to a second cross arm 87, which is
21 mounted to member 88, member 88 being slidable in the X
22 direction along tracks 82. Arm 87 is slidable in a track 85 in
23 member 88 in the Y direction. Motor 81 drives via a first
24 screw 91 member 88 and thus arm 87 in the X direction and also
25 via a second screw 91a or other suitable linkage in the Y
26 direction.

27 The sequence of operation of pick and place mechanism
28 80 is shown in FIGS. 4 through 7. FIG. 4 shows a wafer 72 on
29 alignment and lifting mechanism 90. The wafers may comprise,
30 e.g., 6 or 8 inch silicon semiconductor substrates. Alignment

1 and lifting mechanism 90 includes a vacuum chuck 94. The
2 processed wafer 72 has been removed from chamber 12 of the
3 machine. Pick and place mechanism arm 83 is driven from its
4 prior position, which is shown by the phantom line in FIG. 4 at
5 92, so that vacuum chuck 84 is just below the lower surface of
6 substrate 72 on vacuum chuck 94. Vacuum chuck 94 at this point
7 is deactivated and vacuum chuck 84 activated, so that wafer 72
8 is picked up by vacuum chuck 84. Arm 83 is now driven
9 horizontally to the left and then vertically upward and to the
10 right to the position adjacent cassette 75 at which the
11 processed wafer is to be inserted. This is shown by the
12 position of the arm 83 shown in phantom near cassette 73 in
13 FIG. 4. Arm 83 is then driven further in the X-direction so as
14 to place the substrate into a slot of the cassette. As an
15 example, the last, or top slot of cassette 75 has been chosen
16 in FIGS. 4 and 6. As shown in FIG. 6, once a processed wafer
17 has been inserted into the last position in cassette 75, arm 83
18 is driven to the left in the X direction, as shown by the arrow
19 83a, and then vertically downward to a position adjacent
20 cassette 76 so that an unprocessed wafer can be picked up by
21 vacuum chuck 86. If the last position of cassette 75 had not
22 been reached, arm 87 would have moved upward one position to
23 retrieve the next wafer (unprocessed) in cassette 75. Assuming
24 only processed wafers remain in cassette 75, however, arm 87
25 traverses to cassette 76 to remove an unprocessed wafer. Each
26 cassette 75 and 76 can at any time contain both processed and
27 unprocessed wafers. It is not necessary that one cassette
28 contain only processed wafers and the other cassette
29 unprocessed wafers.

30 Assuming that a processed wafer has been placed in

1 the uppermost position of cassette 75, the arm 83 will travel
2 to the left in FIG. 6 as shown, and then vertically downward to
3 a position adjacent the sixth position from the bottom of
4 cassette 76. (Assuming five wafers have already been removed
5 from cassette 76 and are now in chamber 12 and on load-lock arm
6 160 -- to be explained in greater detail later.) Accordingly,
7 arm 83 moves so that vacuum chuck 86 enters the cassette 76 to
8 remove an unprocessed wafer therefrom. Arm 83 then moves in
9 the X direction to the right as shown by the arrow 83b, and
10 then moves downwardly in the vertical direction to a position
11 adjacent the right side of the vacuum chuck 94. Vacuum chuck
12 94 is now activated and vacuum chuck 86 deactivated.
13 Accordingly, wafer 72 is left in the position shown by the
14 dotted lines on top of vacuum chuck 94. Arm 83 then moves to
15 the right to the home position 83c shown in FIG. 7, so it is
16 out of the way of vacuum chuck 94.

17 As shown in FIG. 8, a wafer 72 may be placed on
18 vacuum chuck 94 slightly off center from the center 95 of
19 vacuum chuck 94. It is necessary to align the center of the
20 substrate with the center 95 of vacuum chuck 94. Accordingly,
21 lifting table 90 includes an aligning means comprising four
22 radially disposed movable members 102 mounted on support 98.
23 Radially disposed members 102 include aligning pins 109. When
24 it is necessary to align substrate 72, vacuum chuck 94 moves
25 vertically downward, as shown in FIG. 7. At the same time,
26 vacuum is removed from vacuum chuck 94 and radially disposed
27 members 102 move radially inwardly, as shown in FIG. 9, thus
28 biasing pins 109 against wafer 72 and aligning wafer 72 with
29 the center axis of vacuum chuck 94. The movable members 102
30 may be guided radially on guide rods 114 or by any other

1 suitable operating mechanism. Wafer 72 may also include an
2 indexing mark or flat spot, for example, flat spot 111. It may
3 be necessary to align the flat spot properly on vacuum chuck 94
4 so that the wafer is properly inserted into chamber 12.
5 Accordingly, vacuum chuck 94 holding wafer 72 is rotated as
6 shown by arrow 112. Proper orientation of the index mark 111
7 may be determined by a light source and light sensor, for
8 example, a light source 113 (See FIG. 13) disposed near the
9 intermediate load-lock 120 and a light sensor 113a disposed on
10 support 98. Other indexing marks can be used instead of a flat
11 spot, for example, a small notch in the substrate 72.

12 Once the substrate has been centered and aligned,
13 support 98 is driven along guide rails 130 and 131 vertically
14 by a suitable actuating means 132, as shown by the phantom
15 lines in FIG. 7. Substrate 72 is raised into a recess 122
16 disposed in a housing 124 defining chamber 110 for maintaining
17 a controlled environment therein. Housing 124 includes an
18 aperture therein defined by an upstanding circular wall 126. A
19 top seal cover 128 is movable in the vertical direction, and
20 when in contact with upstanding wall 126, seals controlled
21 environment chamber 110 from the outside via O-ring seals 129.
22 Lift table support 98 includes a sealing surface 133 which
23 seals via O-ring seal 131a with housing 124 when it engages
24 housing 124. The operation of the load-lock thus formed is
25 shown more clearly in FIGS. 10 and 11.

26 As shown in FIG. 10, the intermediate load-lock 120
27 is provided in order to maintain the purity of the atmosphere
28 in the controlled environment 110, which essentially may
29 comprise an environment of dry nitrogen gas, as it is desired
30 to prevent as much water vapor and other contaminants as

possible from being introduced into the main chamber 12. Accordingly, prior to removing top seal 128, which is movable in a vertical direction as shown, nitrogen gas is introduced via a valve 134 into the volume 122. At the same time, a valve 135 is opened thereby to remove the existing atmosphere in chamber 122. Once dry nitrogen gas has been introduced into chamber 122 for a sufficient period of time and the existing atmosphere has been purged, it is necessary to adjust the pressure in chamber 122 so that it approximates the pressure in the controlled environment 110. Accordingly, a bleed valve 137 is activated to allow the pressure in controlled environment 110 to equalize substantially with the pressure in chamber 122. Once the pressure has equalized, top seal 128 is opened, as shown in FIG. 10, and transfer arm 140, which is shown in greater detail in FIG. 12, enters the opened chamber 122 and vacuum chucks 142 disposed on the transfer arm 140 end section 145 engage the wafer 72 for removing the wafer from chamber 122. See FIGS. 11 and 12. In FIGS. 11 and 12, transfer arm 140 is shown engaging wafer 72. Transfer arm 140 enters chamber 122 slightly below the level of wafer 72, and once in position, moves vertically upward so that vacuum chucks 142 engage wafer 72 and remove it from vacuum chuck 94. Alternatively, vacuum chuck 94 may be allowed to lower instead, thus dropping wafer 72 onto transfer arm 140.

FIG. 12 shows the operation of transfer arm 140 in greater detail. FIG 12 is a top view of the transfer arm 140 and load-lock arm 160. Transfer arm 140 is pivotably mounted as shown at 147 and driven by a motor 143. See FIG. 13. Top seal cover 128 and the mechanism 133 for operating the top seal cover, which may comprise a hydraulic cylinder or other

1 activating device, are shown. See also FIGS. 1, 2 and 13.
2 Transfer arm 140 includes a straight section 144 and a
3 crescent-shaped section 145 having disposed thereon vacuum
4 chucks 142. Vacuum chucks 142 may comprise a recessed groove
5 having a square configuration leading to a vacuum source, as
6 shown. The purpose of transfer arm 140 is to receive
7 unprocessed wafers from vacuum chuck 94 and deliver them to
8 load-lock arm 160 and conversely, to receive processed wafers
9 from load-lock arm 160 and deliver them to vacuum chuck 94.
10 The purpose of load-lock arm 160 is to supply wafers to be
11 processed to the load-lock station 20 of chamber 12 and to
12 retrieve processed wafers from load-lock station 20 and deliver
13 them to a position whereby transfer arm 140 can retrieve them
14 to return them to vacuum chuck 94, which then eventually
15 returns them to cassettes 75 and 76. Load-lock arm 160 is
16 rotatable about pivot point 163 in the plane of FIGS. 14 and 15
17 and also about an axis 167 as shown.

18 With reference to FIGS. 15A and 15B, the operation of
19 transfer arm 140 and load-lock arm 160 will now be explained.
20 FIGS. 15A and 15B are a schematic illustration of the positions
21 of load-lock 20, load-lock arm 160, transfer arm 140 and
22 intermediate load-lock top seal 128 during a complete machine
23 cycle. In FIGS. 15A and 15B, "O" designates "open", "C"
24 designates "closed," "U" designates "unprocessed" and "P"
25 designates "processed." With reference to FIGS. 12, 14, 15A
26 and 15B, the operation is as follows. Transfer arm 140 moves
27 from the position shown in FIG. 14 at A to the position shown
28 at B in FIG. 14, at which it receives a new wafer from vacuum
29 chuck 94. Top seal 128 is open at this time as shown in FIG.
30 15A(a). Transfer arm 140 continues along the arcuate path

1 defined by the arrows 141 to position C as shown in FIG. 14 and
2 eventually places an unprocessed wafer upon the upper vacuum -
3 chuck 162 of load-lock arm 160 at point D. This is shown in
4 FIG. 15A(a). At this point load-lock 20 is closed and transfer
5 arm 140 moves to point C in FIG. 14. Load-lock arm 160 as
6 shown in FIG. 15A(b) now rotates 180° about axis 167, thus
7 placing the unprocessed wafer at the bottom and the processed
8 wafer which has already been removed from the load-lock 20 on
9 top. Transfer arm 140 returns to position D shown in FIG. 14
10 and the processed wafer is now removed by transfer arm 140 as
11 shown in FIG. 15A(c), and returned to the intermediate load-
12 lock 120 as shown at FIG. 15A(d), whereby the processed wafer
13 is returned to one of the cassettes 75 or 76. The next step,
14 as shown in FIG. 15A(e), is the rotation of load-lock arm 160
15 90° about axis 167 so that the unprocessed wafer faces away
16 from the load-lock 20. Load-lock 20 now opens as shown in FIG.
17 15A(f), and load-lock arm 160 rotates about pivot 163 90°
18 clockwise so that the empty vacuum chuck of load-lock arm 160
19 facing load-lock 20 can retrieve a processed wafer from load-
20 lock 20. Once a processed wafer has been engaged by the load-
21 lock arm 160, load-lock arm 160 pivots counterclockwise 90° as
22 shown in FIG. 15A(g). Accordingly, a processed wafer and an
23 unprocessed wafer are now disposed upon the two vacuum chucks
24 of load-lock arm 160 as shown in FIG. 15A(g). Load-lock arm
25 160 now rotates 180° about axis 167 as shown in FIG. 15B(h), so
26 that the unprocessed wafer faces the load-lock 20. Load-lock
27 arm 160 now rotates 90° about pivot 163, and the unprocessed
28 wafer which had been placed on the load-lock arm 160 in step
29 15A(a), is now inserted into load-lock 20 when load-lock arm
30 160 pivots 90° clockwise around point 163. This is shown at

1 step 15B(i). Load-lock arm 160 pivots about pivot point 163
2 90° counterclockwise as shown at step 15B(j), and then rotates
3 90° about pivot point 167 as shown at 15B(k), so that the
4 processed wafer now faces downward. Load-lock 20 is closed at
5 this time, and processing of the wafer inserted into chamber 12
6 at step 15B(i) has begun. Transfer arm 140 has, in the
7 meantime, engaged a new unprocessed wafer as shown at step
8 15B(k), and the unprocessed wafer is deposited upon the upper
9 vacuum chuck of load-lock arm 160 as shown at 15B(l), returning
10 the apparatus to the beginning of the cycle, which is the same
11 as that shown in FIG. 15A(a).

12 Accordingly, load-lock arm 160 provides an efficient
13 and versatile way of transferring wafers between transfer arm
14 140 and load-lock 20. The rotation of arm 160 about axes 163
15 and 167 and the provision of two vacuum chucks 162 allow one
16 mechanism, in a minimum amount of time and space, to handle
17 both processed and unprocessed wafers.

18 FIG. 17 is a top sectional view of the apparatus
19 through section lines 17-17 of FIG. 2. As shown, a section is
20 taken through both the load-lock station 20 and a sputtering
21 station 22. Load-lock station 20 includes a front-plane device
22 generally indicated at 27 and sputtering station 22 includes a
23 back-plane device generally indicated at 47 and which is
24 similar to front-plane device 27. Chamber 12 defined by
25 chamber halves 14 and 16 includes index plate generally
26 indicated at 15 which is shown in greater detail in FIG. 26.
27 Index plate 15, as shown in FIG. 26, is driven by motor 18 and
28 has four positions, each of which is provided with a substrate
29 holding device as shown in greater detail in FIG. 24.

30 Before describing the operation of the apparatus with

1 reference to FIGS. 17 through 23, the substrate holding device
2 of FIG. 24 will be described. The substrate holding device
3 forms part of the sealing members A, B, C and D discussed with
4 reference to FIG. 3A, the operation of which will be described
5 in detail below. A portion of the index plate 15 is shown in
6 FIG. 24. Index plate 24 includes four circular cutouts 200
7 (See FIG. 26), of which one is shown in FIG. 24. A plurality
8 of tabs 202, illustratively three, are provided which extend
9 into the cutout 200. A plurality of arc-shaped flat springs
10 208, illustratively three, are attached to respective ones of
11 the tabs 202. At the end of the springs 208 farthest from tabs
12 202, an attachment is made to tabs 214 which extend from an
13 outer ring-shaped sealing member 220. A further inner ring-
14 shaped member 222 is disposed concentrically inside ring-shaped
15 member 220. Ring-shaped member 222 is removably insertable
16 into ring-shaped member 220, and includes a plurality of
17 further spaced arcuate flat springs 224 attached to the ring-
18 shaped member 222 via screws, for example, as shown at 230. At
19 the other ends of springs 224, spring detent members 234,
20 mounted in blocks 235, are disposed. The detent members engage
21 with recesses 244 in outer ring-shaped member 220 and allow
22 ring-shaped member 222 to be decoupled from ring-shaped member
23 220. Detent member 234 is made of an insulating material such
24 as ceramic or a high temperature plastic material so that the
25 ring 222 and substrate 72 can be insulated from the remainder
26 of the apparatus. This allows the substrate 72 to be properly
27 biased, for example, for sputtering and etching operations.

28 Outer ring-shaped member 220 can move perpendicularly
29 to the plane of the index plate 15 with respect to index plate
30 15, and inner ring-shaped member 222 can move perpendicularly

1 with respect to outer ring-shaped member 220 due to the
2 respective springs 208 and 224. The operation of springs 208
3 and 224 will be explained in greater detail below. Ring 222
4 has mounted on the backside thereof tabs 240, which tabs
5 provide a backrest for a substrate 72 held by ring 222. Ring
6 222 also includes a plurality of substrate securing devices
7 238, which are engaged by rotatable locking and unlocking
8 devices 166 which are mounted on load-lock arm 160.

9 As shown in further detail in FIGS. 20 and 21,
10 securing devices 238 include a roughly channel-shaped member
11 241 having a slot 241a and a central aperture therein for
12 receiving a screw or other fastener 242. Attached to the
13 channel-shaped member 241 is a retaining member 245, which can
14 be rotated so that it extends into the area occupied by the
15 peripheral edge of substrate 72 once it is positioned inside
16 inner ring 222. Channel-shaped member 241 is fastened in a
17 slot 247, the slot being provided for adjustment of the
18 position of member 241. Channel-shaped member 241 is pivotably
19 mounted on fastener 242. The channel 241a in channel-shape
20 member 241 is engaged by a pair of longitudinally extending
21 rods 168 extending from locking and unlocking device 166.
22 Locking and unlocking device 166 may comprise, for example, a
23 small servo motor 170 or air or hydraulically actuated member.
24 As shown, locking and unlocking device 166 includes rod members
25 168 at both ends thereof, since load-lock arm 160 is provided
26 with two opposed vacuum chucks 162. As shown in FIGS. 20 and
27 24, channel-shaped member 241 is disposed so that the slot 241a
28 in the member is generally aligned tangentially with inner ring
29 222 when substrate 72 is clamped in place. Accordingly, member
30 245 is disposed so that it extends over the edge of the

1 substrate 72 and substrate 72 is firmly held between tabs 240
2 of ring 222 and members 245. When the load-lock arm 160 is to
3 remove a substrate from the load-lock station 20, vacuum chuck
4 162 approaches the substrate 72. At the same time, unlocking
5 device 166 approaches channel-shaped member 241 so that the
6 rods 168 are in alignment with the slot 241a in channel-shaped
7 member 241. As vacuum chuck 162 engages the substrate 72, the
8 rods 168 of locking and unlocking device 166 engage with the
9 slot 241a in channel-shaped member 241. Once vacuum chuck 162
10 has engaged wafer 72 and rods 168 are engaged in the slot 241a
11 in channel member 241, servo mechanism 170 is actuated to
12 rotate rods 168 90°, as shown in FIG. 21. In this way, member
13 245 slides in an arcuate path so that it is no longer disposed
14 over the edge of substrate 72. In the illustrated embodiment,
15 three securing members 238 are provided spaced equidistantly
16 around ring member 222, and accordingly, three locking and
17 unlocking members 166 are provided. Therefore, all three
18 members 245 are rotated out of the way at the same time.
19 Accordingly, substrate 72 can be removed by vacuum chuck 162.

20 When a substrate 72 is being placed in chamber 12,
21 locking and unlocking members 166 rotate members 245 in the
22 opposite direction so as to secure the wafer to the ring-shaped
23 member 222.

24 Vacuum chuck 162 is illustrative of the vacuum chucks
25 generally used throughout the apparatus of the invention.
26 Generally, vacuum chucks 162 are supplied via vacuum supply
27 lines 260. The face of the vacuum chuck includes an annular
28 depression 262 and at least one lead-in line 264 to depression
29 262 from a central aperture 266. As shown in FIG. 21, load-
30 lock arm 160 is rotatably disposed on a shaft 268, so that

1 either one of the vacuum chucks 162 can enter the load-lock
2 station 20 as discussed with respect to FIGS. 15A and B.

3 Preferably, vacuum check 162 comprises a first member
4 162a which engages the substrate 72 and a second inner member
5 162b. Members 162a and 162b are coupled via a flat spring
6 member 162c which allows member 162a to move transversely to
7 member 162b, thus allowing member 162a to conform to the plane
8 of the substrate being engaged.

9 With reference now to FIGS. 17 and 18, FIG. 17 shows
10 load-lock station 20 to the right with load-lock door 25
11 closed. FIG 18 shows load-lock door 25 in the open position.
12 FIGS. 17 and 18 show index plate 15 rotatably mounted in
13 chamber 12 defined by chamber halves 14 and 16. As shown in
14 FIGS. 17 and 18, front-plane device 27 at load-lock station 20
15 may comprise a motor or hydraulically or air actuated member
16 300 mounted to support 308. The shaft 302 of member 300 is
17 mounted to a first sealing member 304. Sealing member 304
18 preferably comprises a cup-shaped member and a bellows 306 may
19 be provided to protect shaft 302 extending between support
20 member 308 and cup-shaped member 304 and also to provide
21 sealing. Cup-shaped member 304 includes a first sealing
22 surface disposed annularly around the rim thereof, and may
23 comprise, e.g., an O-ring seal 311. Seal 311 of member 304
24 engages with a machined surface of outer ring-shaped member
25 220. Both surfaces of outer ring-shaped member 220 are
26 machined so as to provide a sealing surface, and the other
27 surface of ring-shaped member 220 engages with a sealing
28 surface of an annular extending portion 320 of chamber half 14.
29 An O-ring seal 321 may be provided on portion 320. As will be
30 explained in greater detail later, the O-ring seals 311 and 321.

are provided for maintaining the environment in the load-lock station 20 area 330 or the chambers of each of the other processing stations 21, 22, or 23 isolated from main chamber volume 12a. Coupled to an inner portion of cup-shaped member 304 is a support member 326 which is movable along with cup-shaped member 304 to provide support for substrate 72. Because substrate 72 is held firmly by ring-shaped member 222 which is attached to ring-shaped member 220 via flat springs 224, substrate 72 can move transversely to the plane in which it is disposed by a small amount without damage when member 326 moves toward substrate 72. Although member 326 may be arranged so that it contacts substrate 72, in the preferred embodiment, member 326 only comes into close proximity with substrate 72. At the load-lock station 20, front-plane member 326 is provided with heat sources for heating the entering substrate 72, shown in FIG. 18. This may be performed by suitable electric heaters 390. Vacuum chucks 162 of load-lock arm 160 can then move in once load-lock door 25 has been opened, to engage or release a substrate and to lock or unlock securing members 238 and thus secure or release substrate 72.

With respect to FIGS. 1 and 2, load-lock door 25 is actuated by a suitable mechanism 19 via a shaft 19a pivotably mounted to the door 25 at 19b. Mechanism 19 may comprise, e.g., a motor driven gear rack or a suitable air or hydraulic cylinder.

As shown in FIGS. 17 and 18, the apparatus of the present invention isolates main chamber volume 12a from the area 330 defining the load-lock. Accordingly, once chamber 330 has been isolated from main chamber 12, as shown in FIG. 18, the atmosphere in chamber 330 may be purged via a valve member

1 (not shown), and the pressure in chamber 330 equalized with
2 that of the controlled environment 110 existing on the other -
3 side of the load-lock door. Once the pressures have been
4 equalized, the load-lock door can be opened, and vacuum chuck
5 162 of load-lock arm 160 can enter the load-lock area 330 to
6 pick up or release the substrate 72, depending upon whether a
7 processed substrate is being removed or an unprocessed
8 substrate inserted. This is shown in FIG. 18. As shown in
9 FIG. 18, springs 208 which couple index plate 15 and outer ring
10 220, allow ring-shaped member 220 and thus the inner ring 222
11 and substrate 72 itself to move outwardly toward the load-lock
12 door 25 so that the mentioned sealing of the area 330 defined
13 by the cup-shaped member 304, ring-shaped member 220 and
14 extending member 320 of chamber half 14 can be accomplished.

15 After a substrate 72 is inserted into area 330 of
16 load-lock 20, load-lock door 25 is closed and the area 330
17 pumped by a mechanical vacuum pump (not shown) and then by
18 vacuum pump 40d. The vacuum level is equalized with the level
19 in volume 12a and then front-plane cup-shaped member 304 moves
20 away from ring-shaped member 220 to allow communication between
21 volumes 12a and 330.

22 Similar sealing means are employed at each of the
23 other stations 21, 22 and 23 to isolate the main chamber volume
24 12a from the volume defining the particular station. In FIGS.
25 17 and 18, like components have been provided with like
26 reference symbols for station 20 and station 22, with the
27 exception that the reference numerals for like already
28 introduced elements of station 22 are provided with primes.
29 For example, as shown in FIG. 17 or 18, which are top sectional
30 views taken through the load-lock station 20 and the sputtering

station 22 (shown to the left), as shown by section lines 17 in FIG. 2, the volume 12a is isolated by the seal provided by members 304', 220' and the wall of chamber half 16 and associated seals 311' and 321'. Station 22 as shown in FIGS. 17 and 18, also includes a back-plane device 47, which is similar to front-plane device 27. Stations 21 and 23 include similar devices 37 and 57. Generally, element 326' is moved toward substrate 72 held by inner retaining ring 222' which is disposed in outer ring 220' via flat springs 224' and detents 234', the outer ring being fixed to index plate 15 via flat springs 208' and being engaged by sealing member 304'. Since station 22 may be a sputtering station, station 22 may include a removable cathode support member and cover 370 mounted to manifold 42, to which a target block 372 is affixed via a bolt 374, for example. Other suitable affixing means are shown in copending application Serial No. _____, assigned to the assignee of this application. Target block 372 comprises a usable, expendable material, for example, if aluminum is being deposited onto substrate 72, the target block 372 will comprise a block of aluminum. Designs for target 372 and the cathode area generally are disclosed more fully in copending application Serial Nos. _____ and _____, assigned to the assignee of this application, and reference is made thereto for details. As shown in FIG. 18, cathode support member 370 is attached to a door 431 and is hinged at 380 to a support structure 381 coupled to chamber half 16. O-ring seals 373 are provided for sealing manifold 42 to chamber half 16. Accordingly, access can be obtained to the interior of manifold 42 and to the cathode and target assembly, as necessary, without disturbing any other processing stations.

1 Suitable voltages are applied to target 372 with
2 respect to chamber 12, and target 372 is suitably insulated
3 therefrom by insulator 372a. Additionally, magnetic field
4 generating means for appropriately containing the sputtered
5 plasma in chamber 350 and for providing efficient and uniform
6 deposition on substrate 72 may be provided in area 371 and also
7 near the substrate itself, and reference is made to the above
8 copening applications for details. Furthermore, as already
9 indicated, the substrate 72 may be biased at some suitable
10 voltage, and support ring 222 or 222' is insulated from the
11 rest of the apparatus by insulating detents 234.

12 For process uniformity, for example, for uniform step
13 coverage, an electromagnetic or magnet assembly 371a may be
14 provided on the back-plane members of sputtering stations 22
15 and 23, as shown. The purpose of assembly 371a is to provide
16 substantially uniform ion current density near the substrate
17 72. Reference should be made to the above identified co-
18 pending application Serial No. _____ for details.

19 As shown in FIG. 18, back-plane device 47 operates to
20 displace member 326' so that it engages substrate 72 mounted in
21 support ring 222'. Since support ring 222' is resiliently
22 mounted due to the flat springs 224' coupling it to outer ring
23 member 220', which in turn is resiliently coupled by flat
24 springs 208' to index plate 15, member 326' can come into close
25 proximity with substrate 72 without damaging the substrate
26 while at the same time allowing member 304' to bear against
27 ring-shaped member 220', which in turn bears against chamber
28 half 16, thereby sealing volume 350 from volume 12a. O-ring
29 seals 311' and 321' are provided for maintaining a proper seal.
30 Accordingly, the sputtering operation can now be performed

1 against substrate 72 in chamber volume 350 without
2 contaminating the main volume 12a or contaminating any other -
3 station 20, 21 or 23. Once the sputtering operation has been
4 completed, the atmosphere in chamber volume 350 can be purged
5 via vacuum pump 32 and manifold 42, and once the atmosphere in
6 chamber 350 has been purged and the pressures equalized between
7 chamber 350 and chamber volume 12a, back-plane members 304' and
8 326' can be moved out of engagement or proximity with ring-
9 shape member 220' and substrate 72, respectively, thereby
10 allowing the index plate 15 to rotate the processed wafer 72 to
11 the next station.

12 FIG. 19 is a more detailed cross-sectional view of
13 station 22 of the present invention taken along lines 19-19 of
14 FIG. 2. Cryogenic vacuum pump 32 and manifold 42 are shown at
15 the bottom of the figure. Back-plane device 47, including
16 actuator 300' is also shown. In this view, details of the
17 cross-section of wafer holding rings 220' and 222' are shown.
18 As shown, inner wafer retaining ring 222' includes hollow
19 sections 223' in which springs 224' are disposed. As shown
20 more clearly in FIG. 19, vacuum pump 32 maintains the proper
21 vacuum level in chamber 350, which is isolated by sealing ring
22 220' and the O-ring seals 311' and 321' when member 304' biases
23 ring-shaped member 220' against chamber half 16. Back-plane
24 member 326' is provided with electric heater devices 390 which
25 are fed via wire conductors 392. Electric heaters 390 may be
26 necessary in certain instances where it is desired to heat the
27 substrate 72 to an optimum temperature for the particular
28 process being carried out. Additionally, it may also be
29 necessary to cool back-plane member 326' and member 304' to
30 maintain the temperature of substrate 72 at a desired

1 temperature. Accordingly, cooling lines 394 and 395 may be
2 provided for passing a cooling fluid through the back-plane
3 device. Also shown in FIG. 19 are shields 400 and 402, which
4 are provided for shielding retaining ring 222', sealing ring
5 220' and associated components from the plasma generated during
6 the sputtering operation in space 350.

7 FIGS. 22 and 23 show further details of station 22.
8 FIG. 22 shows back-plane member 326' prior to its coming into
9 close proximity with substrate 72 held by inner ring 222'.
10 FIG. 23 shows ring 220' after it has been engaged by back-plane
11 member 304'. Back-plane member 326' is also shown in close
12 proximity with substrate 72. Springs 208' allow sealing ring
13 220' to move toward chamber wall 16. As shown in FIG. 23,
14 springs 208' have been deflected by the force exerted by member
15 304' against ring member 220'. O-ring seals 311' and 321' seal
16 volume 12a from volume 350. Springs 224' allow for slight
17 movement of ring member 222' and accordingly, substrate 72,
18 with respect to ring 220', thus preventing damage to substrate
19 72 when back-plane member 326' comes into close proximity
20 therewith.

21 FIGS. 22 and 23 show further details of the cooling
22 means provided at each of the sputtering stations. For
23 example, fluid cooling lines 410 may be provided to cool the
24 support structure in the area of the substrate 72. The various
25 cooling lines are shown in FIG. 25 at 437. Additional cooling
26 lines may be provided in the area of target 372 as shown at 412
27 and 412a. Furthermore, the various fasteners, for example,
28 screws 414 which fasten shield 402 to back-plane member 326',
29 generally are provided either with heads with drilled vent
30 holes or the member to which they are fastened is provided with

1 vents 416. Such vents or drilled heads are necessary in order
2 that pockets of air not be trapped beneath the fasteners during
3 assembly, which might otherwise later contaminate the evacuated
4 volumes.

5 As shown in the drawings, inner ring-shaped member
6 222' remains in contact with substrate 72 during the
7 performance of each process step, thus preventing particulate
8 formation and breakage of substrate 72 which might otherwise
9 occur if substrate 72 were transferred between different
10 handling mechanisms.

11 FIG. 25 is a right side view of the overall apparatus
12 shown in FIG. 1. The overall layout of stations 20, 21, 22 and
13 23 and the various pumps is shown therein. As shown in FIG.
14 25, chamber half 16 is hinged to chamber half 14 at 425.
15 Suitable locking devices are provided at 427 and shown in
16 sectional view in FIGS. 17 and 18 to lock chamber halves 14 and
17 16 together. Further hinges 380 allow each of the right side
18 manifold doors of station sections 21, 22 and 23 mounted to
19 chamber half 16 to be opened, for example, for replacement of
20 targets at stations 22 and 23. A station door is shown at 431,
21 for example, in FIG. 18 and FIG. 25. Suitable locking members
22 429 can be provided for locking each of the right-side station
23 doors in position. FIG. 18 shows station 22 door 431 holding
24 cathode and target support member and cover 370 in the opened
25 position in phantom view, for example. Member 370 may be
26 secured to the station door by bolts or other suitable locking
27 or fastener members.

28 In the illustrated embodiment, station 21 is an
29 etching station, and accordingly, a cathode and associated
30 cover is not provided. Also, because station 20 is the load-

1 lock, as shown in FIG. 25, no door need be provided at that
2 station.

3 In the foregoing specification, the invention has
4 been described with reference to a specific exemplary
5 embodiment thereof. It will, however, be evident that various
6 modifications and changes may be made thereunto without
7 departing from the broader spirit and scope of the invention as
8 set forth in the appended claims. The specification and
9 drawings are, accordingly, to be regarded in an illustrative
10 rather than in a restrictive sense.
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The invention thus provides:

Apparatus for transporting a wafer-like article and subjecting the article to at least one process step comprising:

means defining a first chamber maintained substantially continuously at a vacuum or pressure level;

aperture means in said first chamber through which an article to be subjected to the process step can be introduced into the first chamber;

means in said first chamber for receiving and holding the article;

means for moving the article held by said receiving and holding means substantially in a plane of movement to a position in the first chamber adjacent where the process step is to be performed on the article;

movable means for isolating the second chamber from communication with said first chamber while said process step is performed on the article and for thereafter opening said second chamber to the first chamber so that the second chamber is in communication with the first chamber after the article has been subjected to the process step, said receiving and holding means remaining in contact with the article during the performance of the process step; and

means for removing the article from said first chamber after the article has been subjected to the process step.

Such apparatus wherein said moving means comprises rotatable plate means disposed for movement in said plane of movement and said means for removing

the article comprises said aperture means through which the article is inserted into the first chamber.

Such apparatus wherein said receiving and holding means comprises:

first means coupled to said plate means and defining an inner open area;

first resilient means coupling said plate means and first means;

second means disposed in said inner open area and coupled to said first means, said second means defining a further area contained within said inner open area for receiving the article; and

second resilient means coupling said second means to said first means.

Such apparatus wherein said first means comprises sealing surfaces on first and second surfaces thereof, and said movable means comprises:

closure means movable toward and away from one of the first and second surfaces and having a surface for engaging in sealing relationship with said one of said first and second surfaces of said first means;

said means defining the first chamber having a further surface for engaging in sealing relationship with the other of the first and second surfaces of said first means;

said first resilient means allowing said closure means to bias said other of said first and second surfaces of the first means against the further surface of said means defining the first chamber in a direction substantially

perpendicular to the plane of said plate means,

whereby, when said closure means engages said one of said first and second surfaces and said other of said first and second surfaces engages the further surface, said second chamber is sealed from said first chamber.

Such apparatus wherein said first and second resilient means each comprise flat spring means.

Such apparatus wherein said article comprises a circular wafer and said first means comprises first ring-shaped member means, said second means comprises second ring-shaped member means and said first and second resilient means comprise arcuate flat spring means.

Such apparatus wherein said closure means comprises cup-shaped means with said surface of said closure means for engaging in sealing relationship comprising a rim of said cup-shaped means.

Such apparatus wherein said second means is removably coupled to said first means by electrically insulating detent means.

Such apparatus wherein said first and second means are disposed concentrically and said first resilient means is disposed between said plate means and said first means and said second resilient means is disposed between said second means and said first means.

Such apparatus further
 comprising backing means coupled to said closure means and
 disposed in an area defined by the interior of said closure
 means for coming into close proximity with a surface of the
 article held in said second means when said closure means moves
 toward said one of said first and second surfaces.

Such apparatus wherein said
 second resilient means comprises means for allowing the article
 to move substantially perpendicularly to a plane defined by
 said first means when said backing means comes into close
 proximity with said article.

Such apparatus wherein said
 second ring-shaped member means includes an edge along at least
 a part of an inner periphery thereof extending into the further
 area against which peripheral portions of the article can be
 received, and further comprising clamping means disposed on
 said second means for clamping the article to the second means
 and movable so that a portion thereof can be moved into a
 position extending over at least a part of the further area
 defined by the inside of the second means.

Such apparatus wherein said
 clamping means is rotatably movable over at least a part of the
 further area defined by the inside of the second means.

Such apparatus further
 comprising door means disposed in said aperture means for
 sealing said first chamber from the external environment.

Such apparatus

comprising a further second chamber defined by said aperture means and said door means, and further comprising further movable means disposed behind said door means for isolating said further second chamber from communication with said first chamber while said article is being introduced into or removed through said aperture means.

Such apparatus

wherein said

rotatable plate means comprises disk means rotatably movable in said first chamber about a central axis, said disk means comprising means for holding a plurality of said receiving and holding means, and said means defining said first chamber comprises means for supporting a plurality of second chambers defining work stations at positions spaced approximately equi-angularly and equi-distantly about said central axis, movable means being provided adjacent each of said second chambers with said disk means being disposed between said movable means and a respective second chamber such that said receiving and holding means are rotated into a position between said respective second chamber and said movable means, said movable means being provided for isolating the respective second chamber from communication with the first chamber while the process step is performed on the article in the second chamber and for thereafter opening the second chamber to the first chamber so that the second chamber is in communication with the first chamber after the article has been subjected to the process step, the process step performed in each of said second chambers thereby being isolated from the process step performed in any other second chamber.

Such apparatus wherein said plate means comprises a plurality of locations equi-angularly spaced about a central axis of the plate means for supporting respective ones of said receiving and holding means, each of said receiving and holding means comprising:

!! first means coupled to said plate means and
!! defining an inner open area;

.. first resilient means coupling said plate means
!! and first means;

!! second means disposed in said inner open area
!! and coupled to said first means, said second means defining a
further area contained within said inner open area for
receiving the article; and

second resilient means coupling said second means to said first means, said first means further comprising sealing surfaces on first and second surfaces thereof, each of said movable means comprising:

closure means movable toward and away from one of the first and second surfaces and having a surface for engaging in sealing relationship with said one of said first and second surfaces of said first means;

.. said means defining the first chamber having a
.. further surface for engaging in sealing relationship with the
.. other of the first and second surfaces of said first means;

.. said first resilient means allowing said closure
.. means to bias said other of said first and second surfaces of
.. the first means against the further surface of said means
defining the first chamber in a direction substantially
perpendicular to the plane of said plate means,

whereby, when said closure means engages said

one of said first and second surfaces and said other of said first and second surfaces engages the further surface, said respective second chamber is sealed from said first chamber.

Such apparatus further comprising pump means associated with each of said second chambers for providing an atmosphere at a defined pressure or vacuum level in the respective second chamber and further comprising gas inlet means for providing a gas into the respective second chamber for the process step.

Such apparatus wherein said work stations comprise a load-lock station including said aperture means whereby the article can be inserted into or removed from the first chamber, a station wherein the article can be subjected to an etching process and at least one station wherein the article can be subjected to a sputter deposition process.

Such apparatus wherein each of said stations comprises door means for allowing individual access to the respective second chamber, and said means defining a first chamber comprises first and second chamber portions engaging in sealing relationship along an approximate center line of the first chamber, thereby allowing said first and second chamber portions to be removably uncoupled to each other to allow access to the interior of said first chamber.

Such apparatus further comprising article handling means for receiving an article to

be subjected to the process step from a carrier member having disposed therein a plurality of said articles and for supplying an article that has been subjected to the process step to the carrier member.

Such apparatus wherein said article handling means comprises:

means for retrieving an article from said carrier member and for placing said article on a movable support member;

first arm means for receiving the article from the movable support member; and

second arm means for receiving said article from said first arm means and for inserting said article into said aperture means in said first chamber.

Such apparatus wherein said first and second arm means are disposed in a third chamber isolated from said first chamber and the external environment.

Such apparatus whereas said first arm means comprises means movable in a first plane and said second arm means comprises means movable in said first plane or in a plane parallel to said first plane.

Such apparatus wherein said third chamber includes entry means for receiving an article from said movable support means, and said movable support means comprises means for engaging in sealing relationship with a sealing surface arranged around said entry means when an

article is inserted through said entry means.

Such apparatus wherein said entry means comprises movable sealing means disposed in said third chamber for forming a fourth chamber in said third chamber about the article isolated from said third chamber.

Such apparatus further comprising valve means for purging the atmosphere in said fourth chamber and for supplying an atmosphere into said fourth chamber having a pressure approximately the same as the pressure in said third chamber.

Such apparatus wherein the atmosphere in said third chamber comprises a substantially inert water-free atmosphere.

Such apparatus wherein said first arm means is movable in an arcuate path and said movable sealing means is movable so as to open said third chamber to said fourth chamber when the pressures in said third and fourth chambers have substantially equalized, thereby allowing access by said first arm means to said article.

Such apparatus wherein said second arm means comprises means pivotable in said first plane or a plane parallel to said first plane so that an end of said second arm means defines an arcuate path for receiving the article from said first arm means at a defined position along said path and further being rotatable about a longitudinal

extent of said second arm means.

Such apparatus wherein said second arm means comprises first and second engaging means disposed on the end of the second arm means, one of said engaging means adapted for receiving an article from said first arm means in the first plane or a plane parallel to the first plane and the other adapted for transferring an article to said first arms means in said first plane or a plane parallel to said first plane, said second arm means being adapted for rotating the article engaged by either of said engaging means about the longitudinal extent of the second arm means so that the article can be inserted into said aperture means in said first chamber by the second arm means or received through said aperture means in said first chamber by said second arm means for transfer to said first arm means.

Such apparatus wherein said first arm means comprises vacuum chuck means, said first and second engaging means of said second arm means comprise vacuum chuck means and further comprising locking and unlocking means for engaging with said clamping means disposed on said second arm means.

The invention thus provides

apparatus for transporting a wafer-like article and subjecting the article to at least one process step comprising:

means defining a first chamber maintained substantially continuously at a vacuum or pressure level;
aperture means in said first chamber through



which an article to be subjected to the process step can be introduced into the first chamber;

means in said first chamber for receiving and holding the article;

a plurality of second chambers in any of which a process step can be performed on the article;

means for moving the article held by said receiving and holding means substantially in a plane of movement to a position in the first chamber adjacent a selected one of said second chambers where the process step is to be performed;

movable means for isolating the selected second chamber from communication with the first chamber while said process step is performed on the article and for thereafter opening said second chamber to the first chamber so that the second chamber is in communication with the first chamber after the article has been subjected to the process step, said receiving and holding means remaining in contact with the article during the performance of the process step; and

means for removing the article from the first chamber after the article has been subjected to the process step.

Such apparatus wherein said moving means comprises rotatable plate means disposed for movement in said plane, said moving means comprises a plurality of means for receiving and holding articles and said means for removing the article comprises said aperture means through which the article is inserted into the first chamber.



Such apparatus wherein said moving means comprises means for moving the article held by said receiving and holding means to a position in the first chamber adjacent the selected one of said second chambers where the process step is to be performed and for moving the article held by said receiving and holding means to a further selected one of said second chambers where a further process step may be performed on the article.

Such apparatus wherein said receiving and holding means comprises:

first means coupled to said plate means and defining an inner open area;

first resilient means coupling said plate means and first means;

second means disposed in said inner open area and coupled to said first means, said second means defining a further area contained within said inner open area for receiving the article; and

second resilient means coupling said second means to said first means.

Such apparatus wherein said first means comprises sealing surfaces on first and second surfaces thereof, and said movable means comprises:

closure means movable toward and away from one of the first and second surfaces and having a surface for engaging in sealing relationship with said one of said first and second surfaces of said first means;

said means defining the first chamber having a



further surface for engaging in sealing relationship with the other of the first and second surfaces of said first means;

said first resilient means allowing said closure means to bias said other of said first and second surfaces of the first means against the further surface of said means defining the first chamber in a direction substantially perpendicular to the plane of said plate means,

whereby, when said closure means engages said one of said first and second surfaces and said other of said first and second surfaces engages the further surface, said second chamber is sealed from said first chamber.

Such apparatus wherein said first and second resilient means each comprise flat spring means.

Such apparatus wherein said article comprises a circular wafer and said first means comprises first ring-shaped member means, said second means comprises second ring-shaped member means and said first and second resilient means comprise accurate flat spring means.

Such apparatus wherein said closure means comprises cup-shaped means with said surface of said closure means for engaging in sealing relationship with said one surface of first means comprising a rim of said cup-shaped means.

Such apparatus wherein said second means is removably coupled to said first means by



electrically insulating detent means.

Such apparatus wherein said first and second means are disposed concentrically and said first resilient means is disposed between said plate means and said first means and said second resilient means is disposed between said second means and said first means.

Such apparatus further comprising backing means coupled to said closure means and disposed in an area defined by the interior of said closure means for coming into close proximity with a surface of the article held in said second means when said closure means moves toward said one of said first and second surfaces.

Such apparatus wherein said second resilient means comprises means for allowing the article to move substantially perpendicularly to a plane defined by said first means when said backing means comes into close proximity with said article.

Such apparatus wherein said second ring-shaped member means includes an edge along at least a part of an inner periphery thereof extending into the further area against which peripheral portions of the article can be received, and further comprising means for clamping the article to said second means, said clamping means comprising means disposed on said second means movable so that a portion thereof can be moved into a position extending over at least a part of the further area defined by the inside of the second means.



Such apparatus, wherein said clamping means is rotatably movable over at least a part of the further area defined by the inside of the second means.

Such apparatus further comprising door means disposed in said aperture means for sealing said first chamber from the external environment.

Such apparatus further comprising a further second chamber defined by said aperture means and said door means between said door means and said first chamber, and further comprising further movable means disposed behind said door means for isolating said further second chamber from communication with said first chamber while said article is being introduced into or removed through said aperture means.

Such apparatus wherein said rotatable plate means comprises disk means rotatably movable in said first chamber about a central axis, said disk means comprising means for holding a plurality of said receiving and holding means, and said means defining said first chamber comprises means for supporting a plurality of second chambers defining work stations at positions spaced approximately equi-angularly and equi-distantly about said central axis, movable means being provided adjacent each of said second chambers for isolating the respective second chamber from communication with the first chamber while the process step is performed on the article in the second chamber and for thereafter opening the second chamber to the first chamber so that the second chamber



is in communication with the first chamber after the article has been subjected to the process step, the process step performed in each of said second chambers thereby being isolated from the process step performed in any other second chamber.

Such apparatus, further comprising pump means associated with each of said second chambers for providing an atmosphere at a defined pressure or vacuum level in the respective second chamber and further comprising gas inlet means for each second chamber for providing a gas into said second chamber for said process step.

Such apparatus wherein said work stations comprise a load-lock station whereby the article can be inserted into or removed from the first chamber, a station wherein the article can be subjected to an etching process and at least one station wherein the article can be subjected to a sputter deposition process.

Such apparatus wherein each of said stations comprises door means for allowing individual access to the respective second chambers.

Such apparatus wherein said means defining a first chamber comprises first and second chamber portions engaging in sealing relationship along an approximate center line of the first chamber, thereby allowing said first and second chamber portions to be removably uncoupled to each other to allow access to the interior of said

first chamber.

Such apparatus further comprising article handling means for receiving an article to be subjected to the process step from a carrier member having disposed therein a plurality of said articles and for supplying an article that has been subjected to the process step to the carrier member.

The invention thus provides apparatus for holding a wafer-like article in a movable support means and for allowing movement transverse to said support means comprising:

first means coupled to the support means and defining a first inner open area;

first resilient means coupling said support means and first means;

second means disposed in said inner open area and coupled to said first means, said second means defining a second inner open area contained within said first area for receiving the article;

second resilient means coupling said second means to said first means; and

means disposed on said second means for securing the article disposed in said second area to said second means.

Such apparatus further comprising a first chamber in which the apparatus is disposed and a second chamber in communication with the first chamber and wherein said first means comprises sealing surfaces on first and second surfaces thereof, one of said first and second



surfaces being engageable in sealing relationship with a surface of wall means of the first chamber in which the apparatus is disposed and the other surface being engageable in sealing relationship with movable closure means for isolating the second chamber from the first chamber while a process step is performed on the article in the second chamber, said closure means comprising means movable toward and away from the article and having a further surface for engaging in sealing relationship with the other surface of the first means, said first resilient means allowing said closure means to bias the one of said first and second surfaces of said first means against said surface of said wall means in a direction substantially perpendicular to the plane of said wall means when said closure means moves toward and engages said other surface of said first means, said second chamber being isolated from said first chamber when said further surface of said closure means engages said other surface of said first means and said one surface of said first means engages with said surface of said wall means.

Such apparatus wherein said wafer-like article is circular in shape and said first means comprises first ring-shaped member means and said second means comprises second ring-shaped member means.

Such apparatus wherein said first and second resilient means each comprise flat, arcuate spring means.

Such apparatus wherein said

closure means comprises cup-shaped means, said further surface of said closure means comprising a rim of said cup-shaped means.

Such apparatus wherein said second means is removably coupled to said first means by detent means.

Such apparatus wherein said first and second ring-shaped means are disposed concentrically, and said first resilient means is disposed between said movable support means and said first means and said second resilient means is disposed between said second means and said first means.

Such apparatus further comprising backing means coupled to said closure means and disposed in an area defined by the inside of said closure means for coming into close proximity with a surface of the article held by said second means when said closure means moves toward said one of said first and second surfaces.

Such apparatus wherein said second resilient means comprises means for allowing the article to move substantially perpendicularly to a plane in which said first means is disposed when said backing means comes into close proximity with said article.

Such apparatus wherein said second ring-shaped means includes an edge along at least a part



of an inner periphery thereof extending into the area defined by the inside of said ring-shaped means against which peripheral portions of the article can be received, and said securing means comprises means disposed on said second means movable so that a portion thereof can be moved into a position over the area defined by the inside of the second ring-shaped means.

Such apparatus wherein at least a part of said securing means is rotatably movable over the area defined by the inside of the second ring-shaped means.

The invention thus provides

method for transporting a wafer-like article and subjecting the article to at least one process step comprising the steps of:

introducing the article to be processed through aperture means into a first chamber maintained substantially continuously at a vacuum or pressure level;

receiving and holding the article in receiving and holding means in the first chamber;

moving the article held by said receiving and holding means to a position in the first chamber adjacent a second chamber where the process step is to be performed; isolating the second chamber from communication with said first chamber while said process step is performed on the article and thereafter opening said second chamber to the first chamber so that the second chamber is in communication with the first chamber after the article has been subjected to the process step, said receiving and holding means remaining in contact with the article during the performance of the process

step, said receiving and holding means remaining in contact with the article during the performance of the process step; and

removing the article from the first chamber after the article has been subjected to the process step.

Such method . wherein said step of receiving and holding comprises clamping the article to said receiving and holding means coupled to support means, said step of moving comprises rotating said support means disposed in the first chamber about a central axis and said step of removing the article comprises removing the article through the aperture means through which the article is inserted into the first chamber.

Such method wherein said step of clamping comprises receiving the article in the interior area of an inner one of two concentric ring means, the outer of the ring means being coupled to the support means by first resilient means and the inner ring means being coupled to the outer ring means by second resilient means.

Such method wherein said outer one of said ring means comprises sealing surfaces on first and second surfaces thereof, and further comprising the steps of:

moving closure means toward and away from one of the first and second surfaces and engaging a surface of the closure means in sealing relationship with said one of said first and second surfaces;

engaging a further surface of the first chamber in sealing relationship with the other of the first and second surfaces;

said first resilient means allowing said closure means to bias said other of said first and second surfaces against the further surface of said first chamber in a direction substantially perpendicular to the plane of said support means, whereby, when said closure means engages said one of said first and second surfaces and said other of said first and second surfaces engages the further surface, said second chamber is sealed from said first chamber.

Such . method further comprising the step of moving a support surface into close proximity to a surface of the article held by said inner ring means during said step of moving said closure means.

Such . method wherein said step of moving a support surface into close proximity to a surface of the article held in said inner ring means further comprises flexing said second resilient means thereby allowing the article to move substantially perpendicularly to a plane defined by said outer ring means.

Such method wherein said ring means includes an edge along at least a part of an inner periphery thereof extending into the interior area thereof against which peripheral portions of the article can be received, and said step of clamping comprises moving clamping means so that a portion thereof can be moved into a position

extending over at least a part of the area defined by the inside of the inner ring means.

Such method wherein said step of clamping comprises rotating said clamping means over at least a part of the area defined by the inside of the inner ring means.

Such method wherein said step of moving comprises rotating said article held in said support means in said first chamber to a position adjacent a selected one of a plurality of second chambers located at positions spaced approximately equi-angularly and equidistantly about a central axis of said support means and isolating the selected second chamber from the first chamber while the process step is performed on the article in the second chamber and thereafter opening the second chamber to the first chamber so that the second chamber is in communication with the first chamber after the article has been subjected to the process step, the process step performed in each of said second chambers thereby being isolated from the process steps performed in any of the second chambers.

Such method wherein said step of isolating comprises moving closure means associated with the respective second chamber toward the article held in said support means to thereby seal said second chamber from the first chamber.

Such method further



comprising the steps of receiving an article to be subjected to the process step from a carrier member having disposed therein a plurality of said articles and supplying an article that has been subjected to the process step to the carrier member.

Such method wherein said step of receiving comprises:

- i. retrieving an article from said carrier member
- ii. and placing said article on a movable support member;
- iii. moving said movable support member to a first intermediate position;
- receiving the article in first arm means movable in a first plane from the movable support member at the first intermediate position; and
- moving said first arm means in said first plane and transferring said article to second arm means at a second intermediate position and moving said second arm means so as to insert said article into said aperture means in said first chamber.

Such method wherein said steps of receiving and transferring are performed in a third chamber isolated from said first chamber and the external environment.

Such method whereas said step of moving said first arm means comprises moving said first arm means in a first plane and said steps of receiving said article from said first arm means and moving said second arm means so as to insert said article into said aperture means

comprises moving said second arm means in said first plane or in a plane parallel to said first plane and rotating said article about the longitudinal extent of said second arm means.

Such method wherein said third chamber includes entry means for receiving an article, and further comprising the step of engaging said movable support means in sealing relationship with a sealing surface arranged around said entry means when an article is inserted through said entry means by said movable support means.

Such method wherein said step of engaging comprises forming a fourth chamber in said third chamber about said article isolated from said third chamber.

Such method further comprising the steps of purging the atmosphere in said fourth chamber and supplying an atmosphere into said fourth chamber having a pressure approximately the same as the pressure in said third chamber.

Such method wherein said step of moving said first arm means comprises moving an end of said first arm means in an accurate path and said step of receiving the article in first arm means comprises the step of opening said third chamber to said fourth chamber when the pressures in said third and fourth chambers have substantially equalized, thereby allowing access by said first arm means to said article.

Such method

further

comprising the step of moving an end of said second arm means pivotably in said first plane or a plane parallel to said first plane in an arcuate path and receiving the article from said first arm means at said second intermediate position along said path and rotating the article about a longitudinal extent of said second arm means.

Such method

wherein said

step of moving said second arm means comprises receiving an article from said first arm means while another of said articles is held by said second arm means and thereafter transferring the other article to said first arms means in said first plane or a plane parallel to said first plane by rotating the article about the longitudinal extent of the second arm means so that the article can be received by said first arm means.

Such method

, further

comprising the steps of receiving an article in said second arm means from said first chamber while another of said articles is held by said second arm means and thereafter transferring the other article to said first chamber by rotating the article about the longitudinal extent of the second arm means so that the article can be inserted through said aperture means into said first chamber.

The invention thus provides a

method for transporting a wafer-like article

and subjecting the article to at least one process step

comprising the steps of:

introducing the article to be processed through aperture means into a first chamber maintained substantially continuously at a vacuum or pressure level;

receiving and holding the article in receiving and holding means in the first chamber;

moving the article held by said receiving and holding means to a position in the first chamber adjacent a selected one of second chambers where the process step is to be performed;

isolating the selected second chamber from communication with the first chamber while said process step is performed on the article and thereafter opening said second chamber to the first chamber so that the second chamber is in communication with the first chamber after the article has been subjected to the process step, said receiving and holding means remaining in contact with the article during the performance of the process step; and

removing the article from the first chamber after the article has been subjected to the process step.

Such method wherein said step of moving comprises rotating support means disposed in the first chamber about a central axis and in which the receiving and holding means is disposed and said step of removing the article comprises removing the article through said aperture means through which the article is inserted into the first chamber.

Such method wherein said step of moving comprises moving the article held by said

receiving and holding means to a position in the first chamber adjacent the selected one of said second chambers where the process step is to be performed and further comprising the step of moving the article held by said receiving and holding means to a further selected one of said second chambers where a further process step may be performed on the article.

Such method wherein said step of receiving and holding comprises receiving the article in the interior area of an inner one of two concentric ring means, the outer of the ring means being coupled to the support means by first resilient means and the inner ring means being coupled to the outer ring means by second resilient means.

Such method wherein said outer one of said ring means comprises sealing surfaces on first and second surfaces thereof, and further comprising the steps of:

moving closure means toward and away from one of the first and second surfaces and engaging a surface of the closure means in sealing relationship with said one of said first and second surfaces;

engaging a further surface of the first chamber in sealing relationship with the other of the first and second surfaces;

said first resilient means allowing said closure means to bias said other of said first and second surfaces against the further surface of said first chamber in a direction substantially perpendicular to the plane of said support means, whereby when said closure means engages said one

of said first and second surfaces and said other of said first and second surfaces engages the further surface, said second chamber is sealed from said first chamber.

Such method further comprising the step of moving a support surface into close proximity to a surface of the article held by said inner ring means during said step of moving said closure means.

Such method wherein said step of moving a support surface into close proximity to a surface of the article held in said inner ring means further comprises flexing said second resilient means thereby allowing the article to move substantially perpendicularly to a plane defined by said outer ring means.

Such method wherein said inner ring means includes an edge along at least a part of an inner periphery thereof extending into the interior area thereof against which peripheral portions of the article can be received, and further comprising the step of moving clamping means so that a portion thereof can be moved into a position extending over at least a part of the area defined by the inside of the inner ring means.

Such method wherein said step of clamping comprises rotating at least a portion of said clamping means over at least a part of the area defined by the inside of the inner ring means.

Such method

wherein said

step of moving comprises rotating said article held in said support means in said first chamber to a position adjacent a selected one of a plurality of second chambers located at positions spaced approximately equi-angularly and equidistantly about a central axis of said support means and isolating the selected second chamber from the first chamber while the process step is performed on the article in the second chamber and thereafter opening the second chamber to the first chamber so that the second chamber is in communication with the first chamber after the article has been subjected to the process step, the process step performed in each of said second chambers thereby being isolated from the process step performed in any of the other second chambers.

Such method

wherein said

step of isolating comprises moving closure means associated with the respective second chamber toward the article held in said support means to thereby seal said second chamber from the first chamber.

Such method

further

comprising the steps of receiving an article to be subjected to the process step from a carrier member having disposed therein a plurality of said articles and supplying an article that has been subjected to the process step to the carrier member.

WHAT IS CLAIMED IS:

1. Apparatus for transporting a wafer-like article and subjecting the article to at least one process step comprising:

means defining a first chamber maintained substantially continuously at a vacuum or pressure level;

aperture means in said first chamber through which an article to be subjected to the process step can be introduced into the first chamber;

means in said first chamber for receiving and holding the article;

means for moving the article held by said receiving and holding means substantially in a plane of movement to a position in the first chamber adjacent where the process step is to be performed on the article;

movable means for isolating the second chamber from communication with said first chamber while said process step is performed on the article and for thereafter opening said second chamber to the first chamber so that the second chamber is in communication with the first chamber after the article has been subjected to the process step, said receiving and holding means remaining in contact with the article during the performance of the process step; and

means for removing the article from said first chamber after the article has been subjected to the process step.

2. The apparatus recited in claim 1, wherein said moving means comprises rotatable plate means disposed for movement in said plane of movement and said means for removing

3. Apparatus for transporting a wafer-like article and subjecting the article to at least one process step comprising:

means defining a first chamber maintained substantially continuously at a vacuum or pressure level;
aperture means in said first chamber through

which an article to be subjected to the process step can be introduced into the first chamber;

means in said first chamber for receiving and holding the article;

a plurality of second chambers in any of which a process step can be performed on the article;

means for moving the article held by said receiving and holding means substantially in a plane of movement to a position in the first chamber adjacent a selected one of said second chambers where the process step is to be performed;

movable means for isolating the selected second chamber from communication with the first chamber while said process step is performed on the article and for thereafter opening said second chamber to the first chamber so that the second chamber is in communication with the first chamber after the article has been subjected to the process step, said receiving and holding means remaining in contact with the article during the performance of the process step; and

means for removing the article from the first chamber after the article has been subjected to the process step.

4. The apparatus recited in claim 3, wherein said moving means comprises rotatable plate means disposed for movement in said plane, said moving means comprises a plurality of means for receiving and holding articles and said means for removing the article comprising said aperture means through which the article is inserted into the first chamber.

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5. Apparatus for holding a wafer-like article in a movable support means and for allowing movement transverse to said support means comprising:

first means coupled to the support means and defining a first inner open area;

first resilient means coupling said support means and first means;

second means disposed in said inner open area and coupled to said first means, said second means defining a second inner open area contained within said first area for receiving the article;

second resilient means coupling said second means to said first means; and

means disposed on said second means for securing the article disposed in said second area to said second means.

6. The apparatus recited in claim 5, further comprising a first chamber in which the apparatus is disposed and a second chamber in communication with the first chamber and wherein said first means comprises sealing surfaces on first and second surfaces thereof, one of said first and second

7. A method for transporting a wafer-like article and subjecting the article to at least one process step comprising the steps of:

introducing the article to be processed through aperture means into a first chamber maintained substantially continuously at a vacuum or pressure level;

receiving and holding the article in receiving and holding means in the first chamber;

moving the article held by said receiving and holding means to a position in the first chamber adjacent a second chamber where the process step is to be performed;

isolating the second chamber from communication with said first chamber while said process step is performed on the article and thereafter opening said second chamber to the first chamber so that the second chamber is in communication with the first chamber after the article has been subjected to the process step, said receiving and holding means remaining in contact with the article during the performance of the process step, said receiving and holding means remaining in contact with the article during the performance of the process step; and

removing the article from the first chamber after the article has been subjected to the process step.

8. The method recited in claim 7, wherein said step of receiving and holding comprises clamping the article to said receiving and holding means coupled to support means, said step of moving comprises rotating said support means disposed in the first chamber about a central axis and said step of removing the article comprises removing the article through the aperture means through which the article is inserted into the first chamber.

9. A method for transporting a wafer-like article and subjecting the article to at least one process step comprising the steps of:

introducing the article to be processed through aperture means into a first chamber maintained substantially continuously at a vacuum or pressure level;

receiving and holding the article in receiving and holding means in the first chamber;

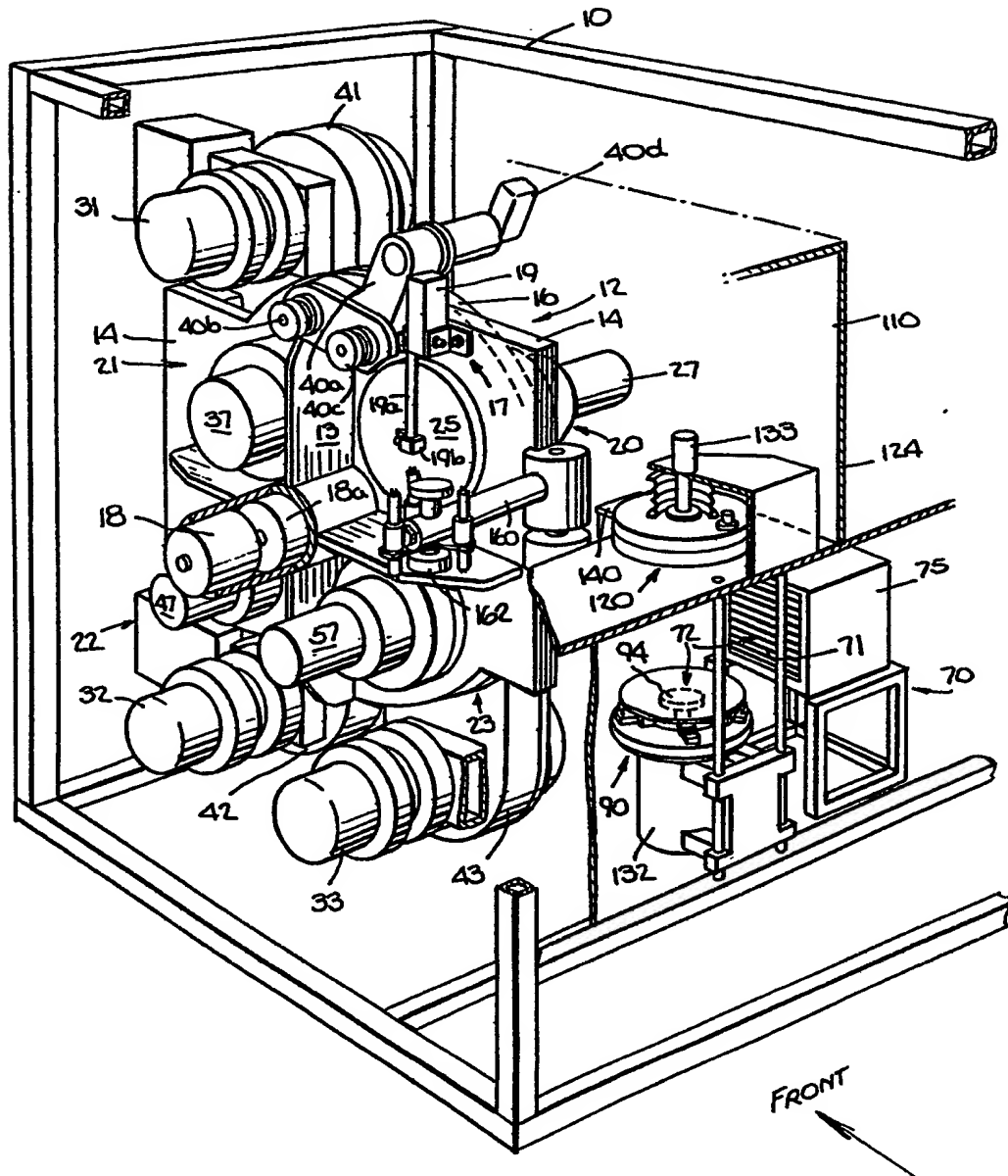
moving the article held by said receiving and holding means to a position in the first chamber adjacent a selected one of second chambers where the process step is to be performed;

isolating the selected second chamber from communication with the first chamber while said process step is performed on the article and thereafter opening said second chamber to the first chamber so that the second chamber is in communication with the first chamber after the article has been subjected to the process step, said receiving and holding means remaining in contact with the article during the performance of the process step; and

removing the article from the first chamber after the article has been subjected to the process step.

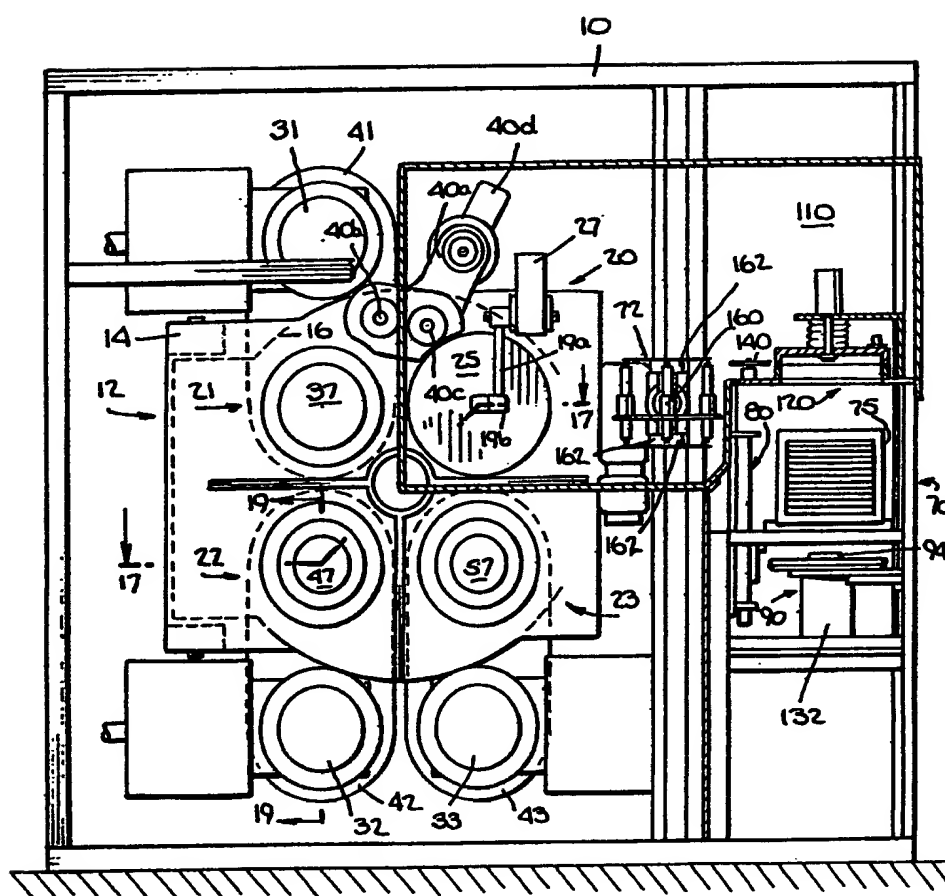
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Fig. 1.



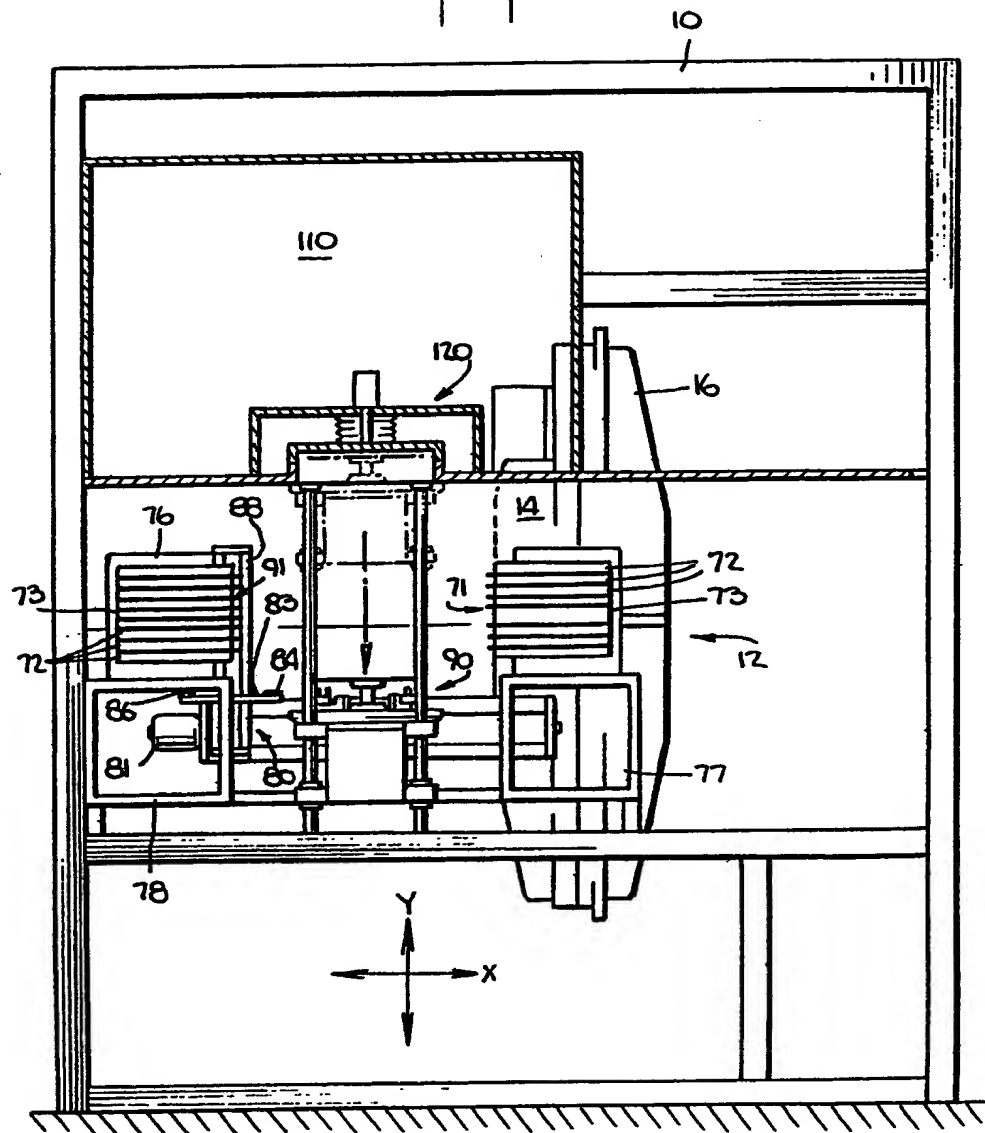
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Fig. 2.



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Fig. 3.



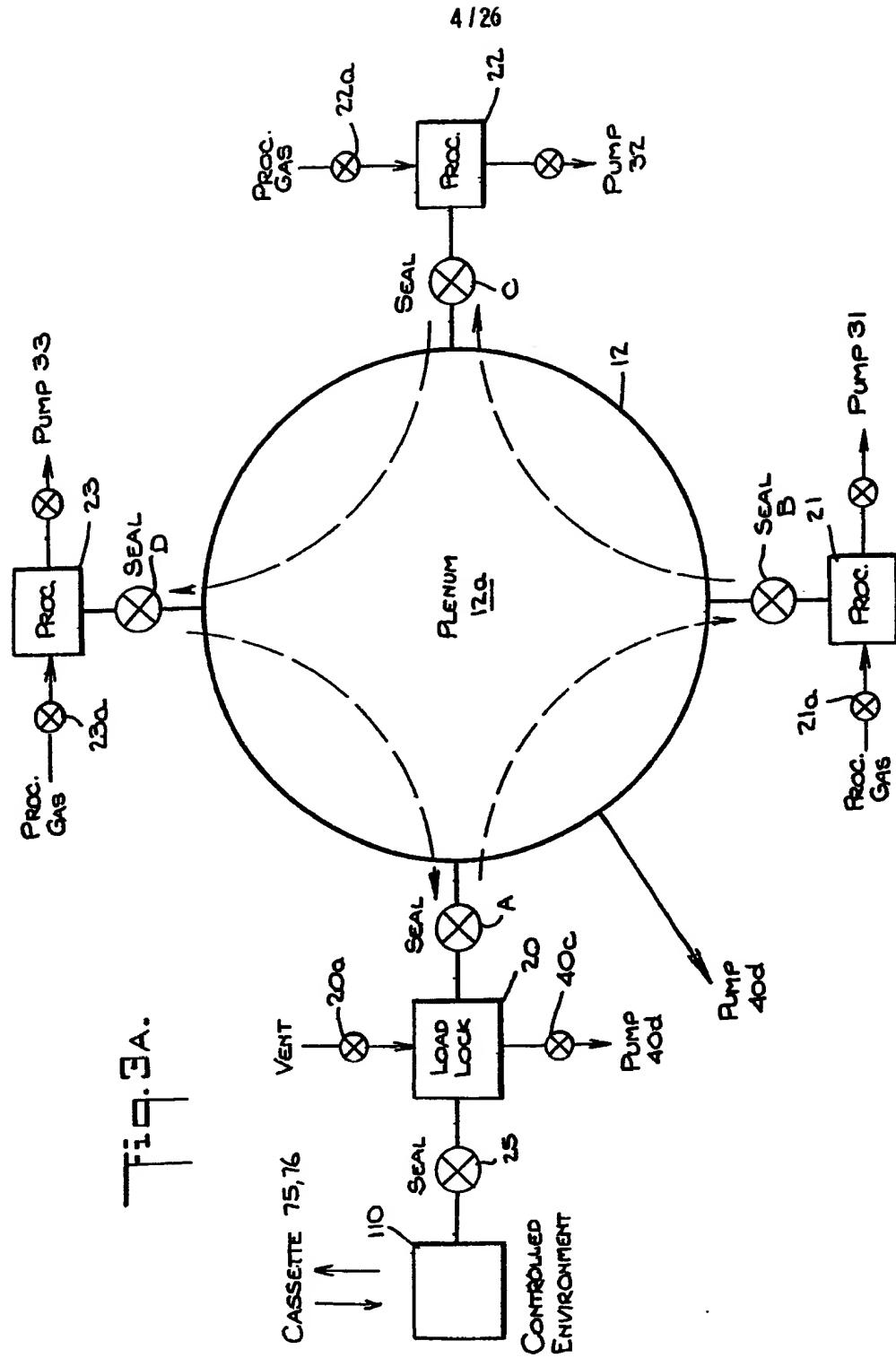


Fig. 3A.

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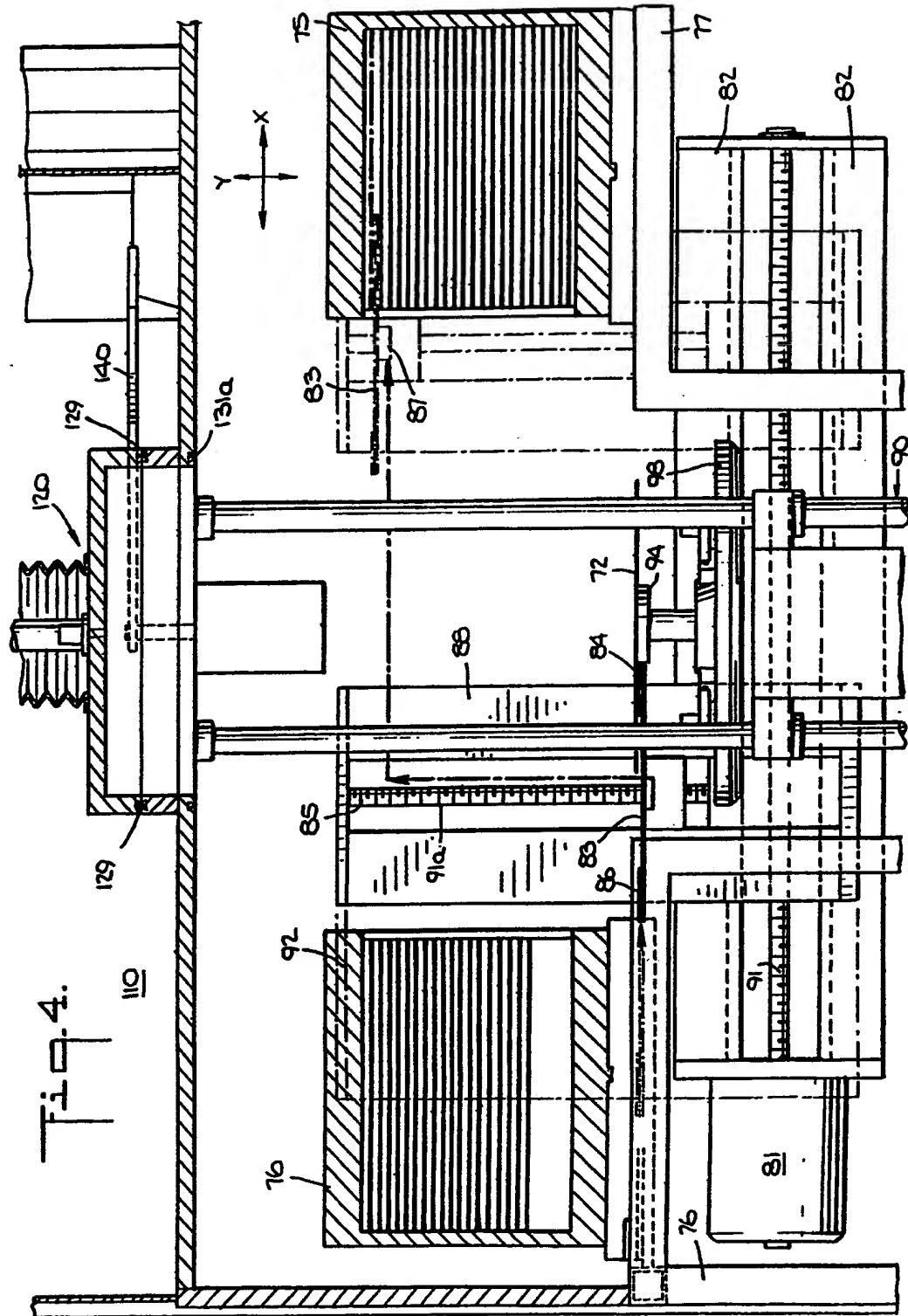
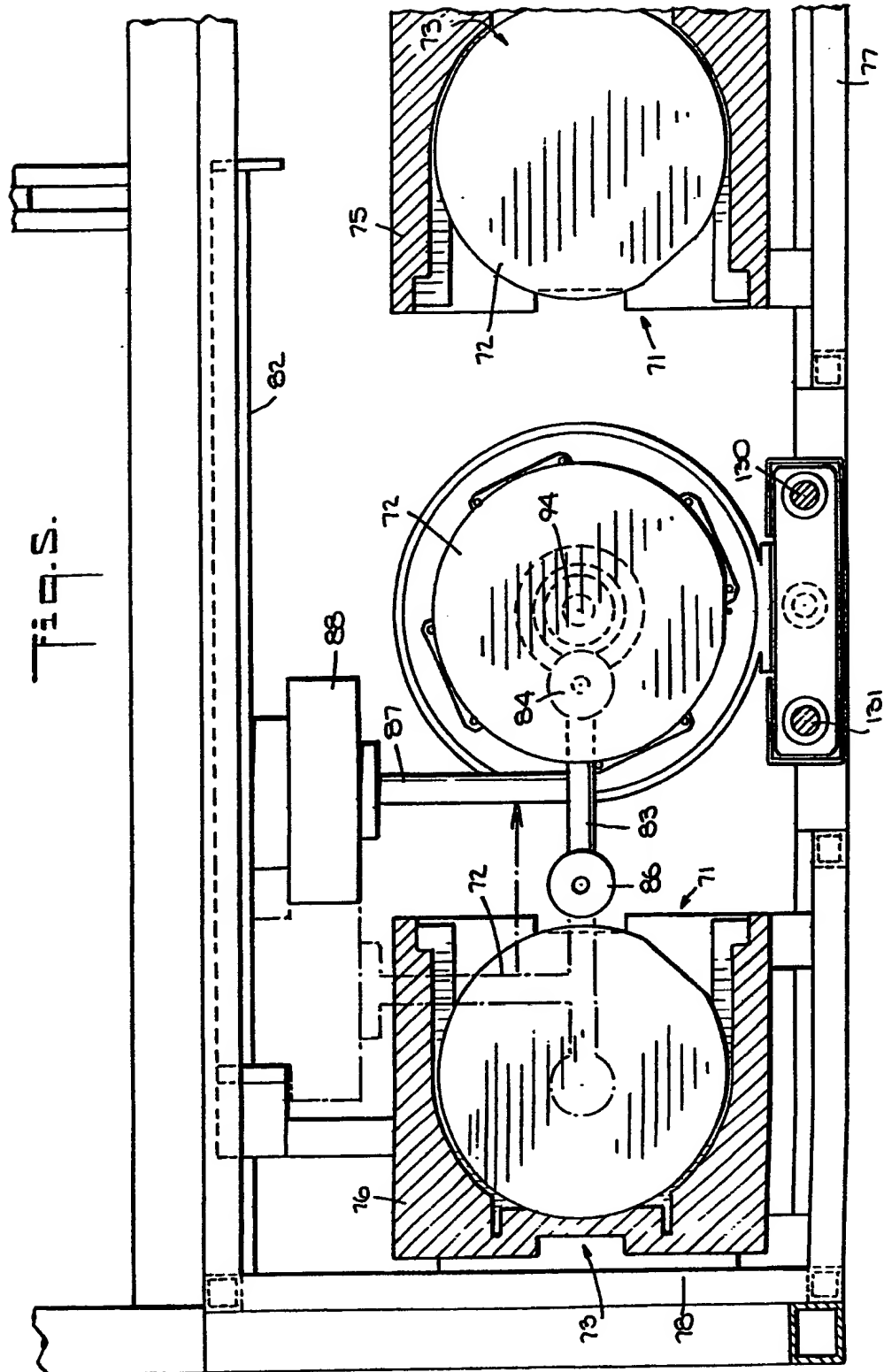


FIG. 10 is a perspective view of the
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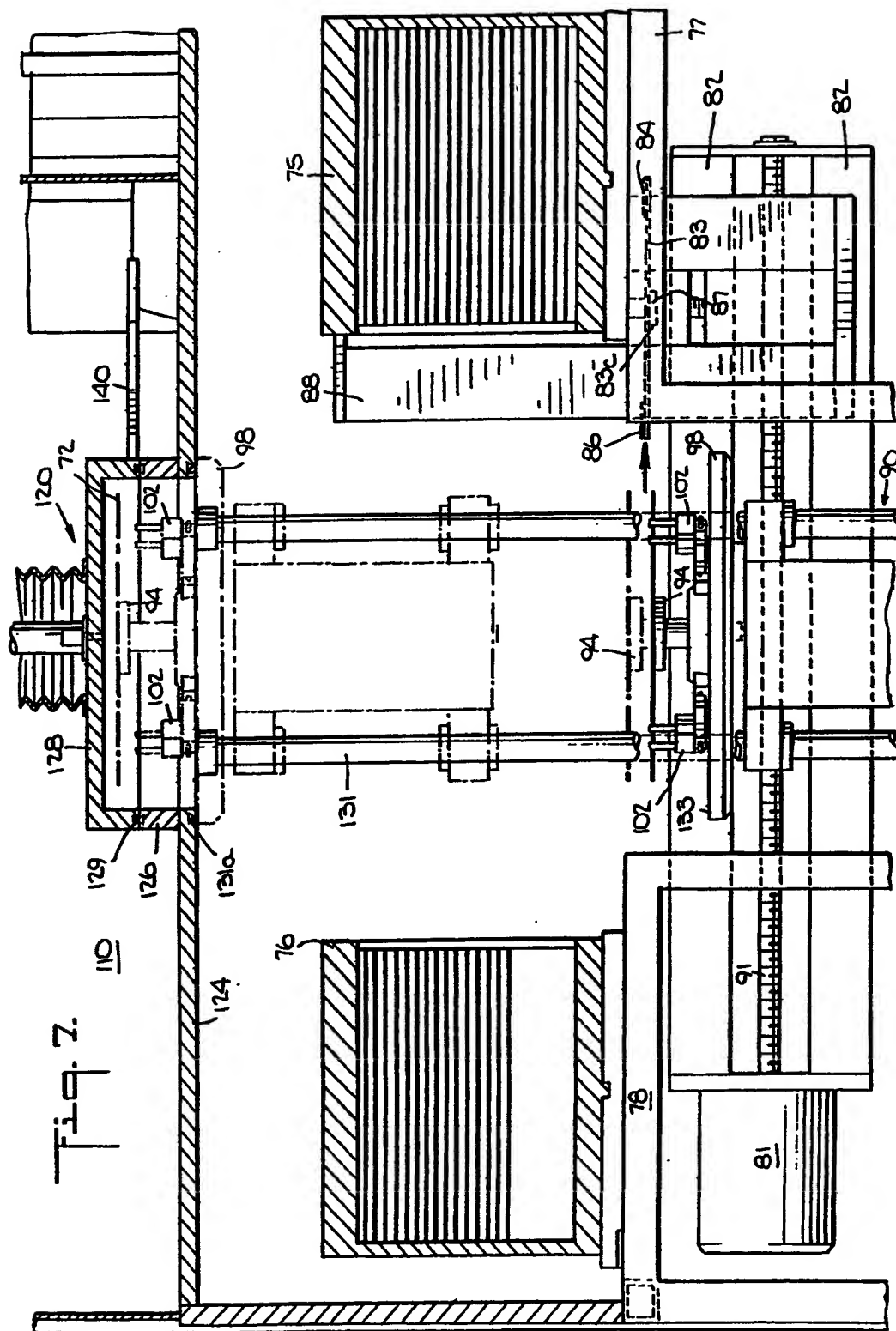
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Fig. 8.

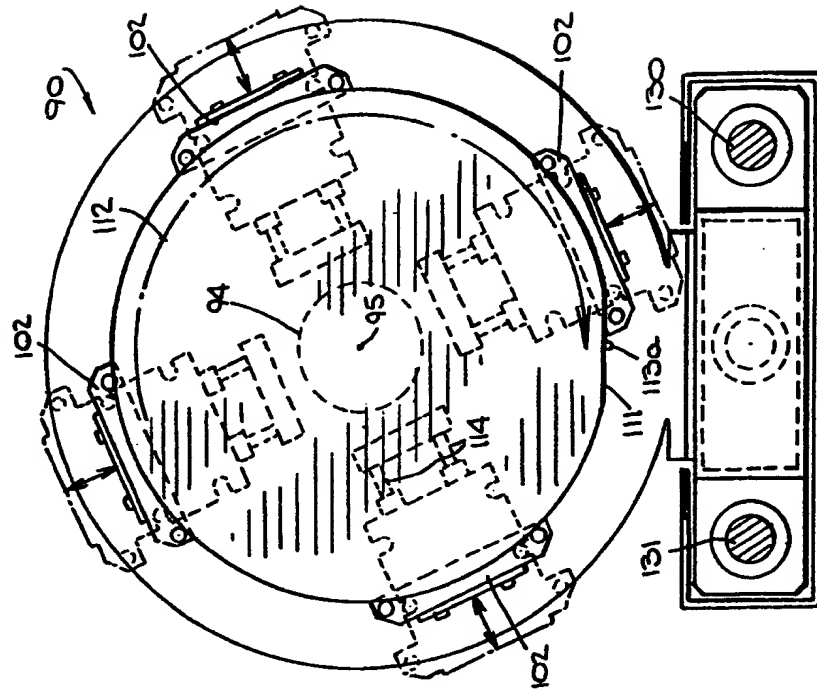
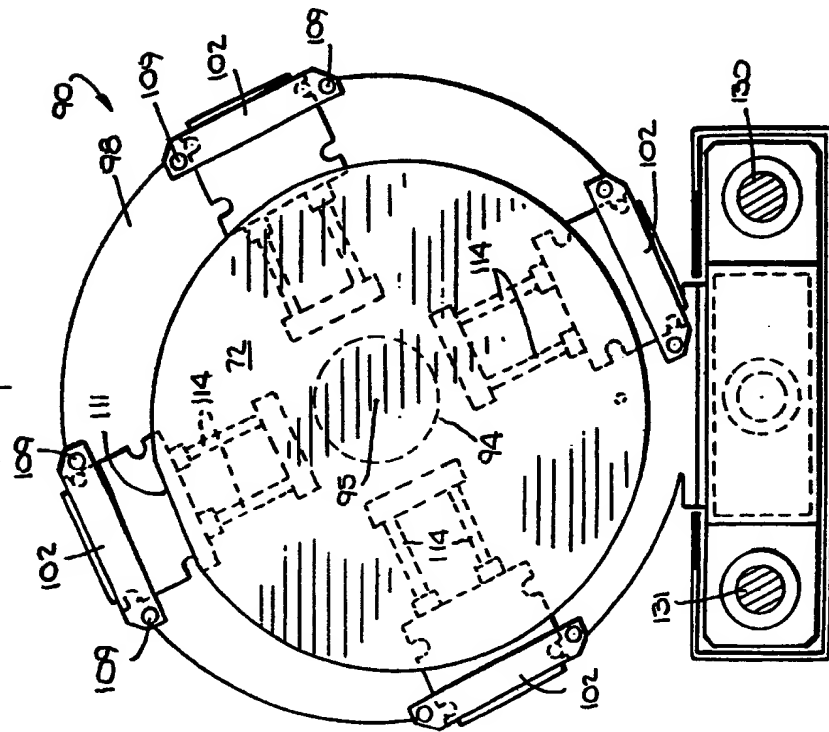
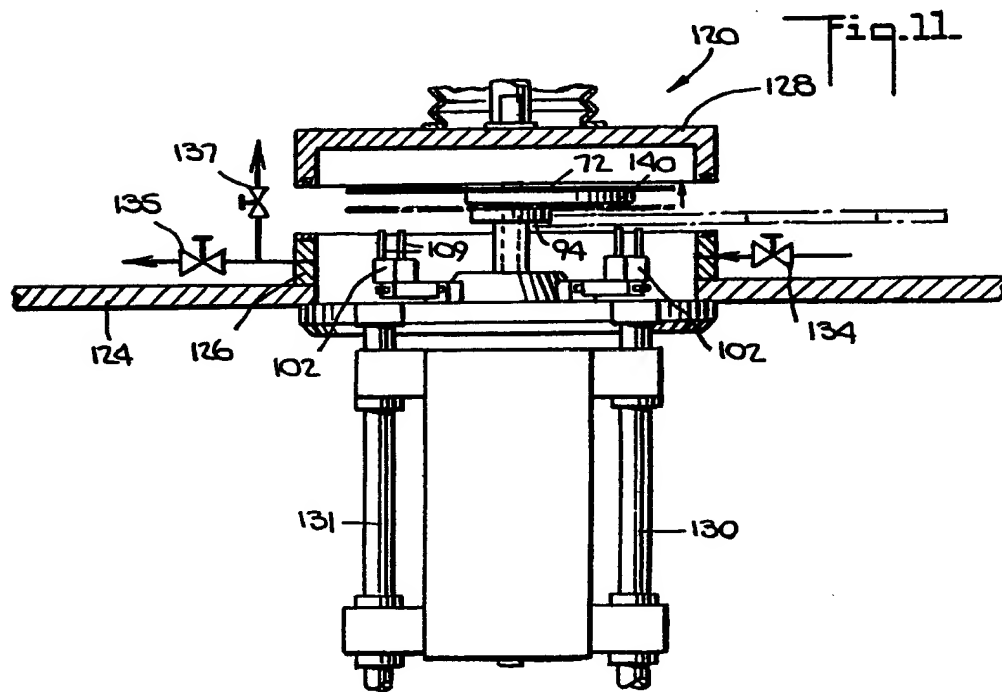
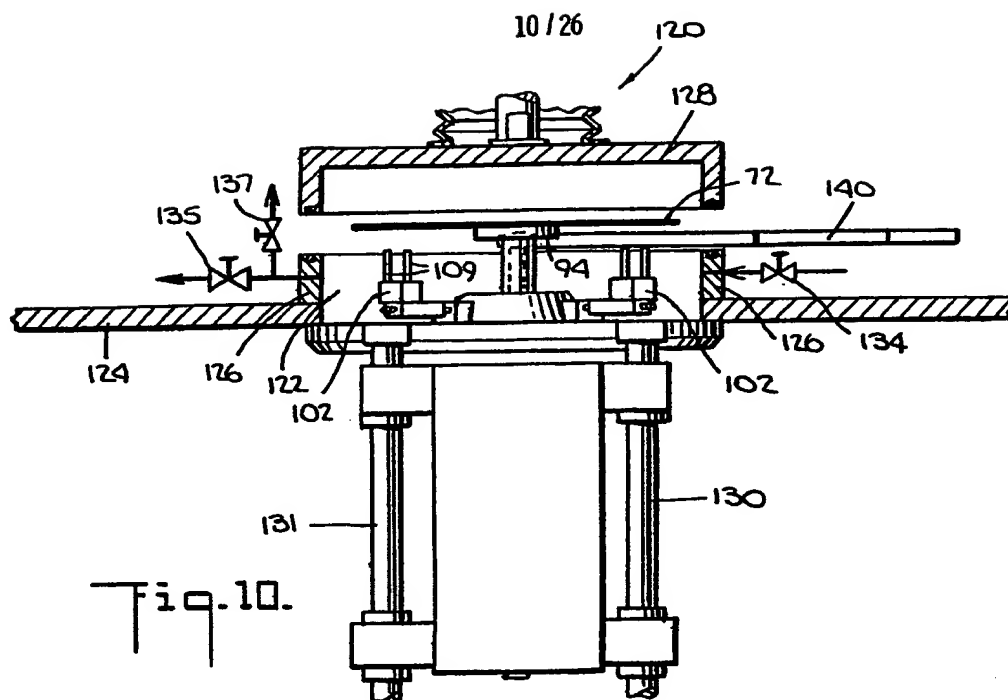


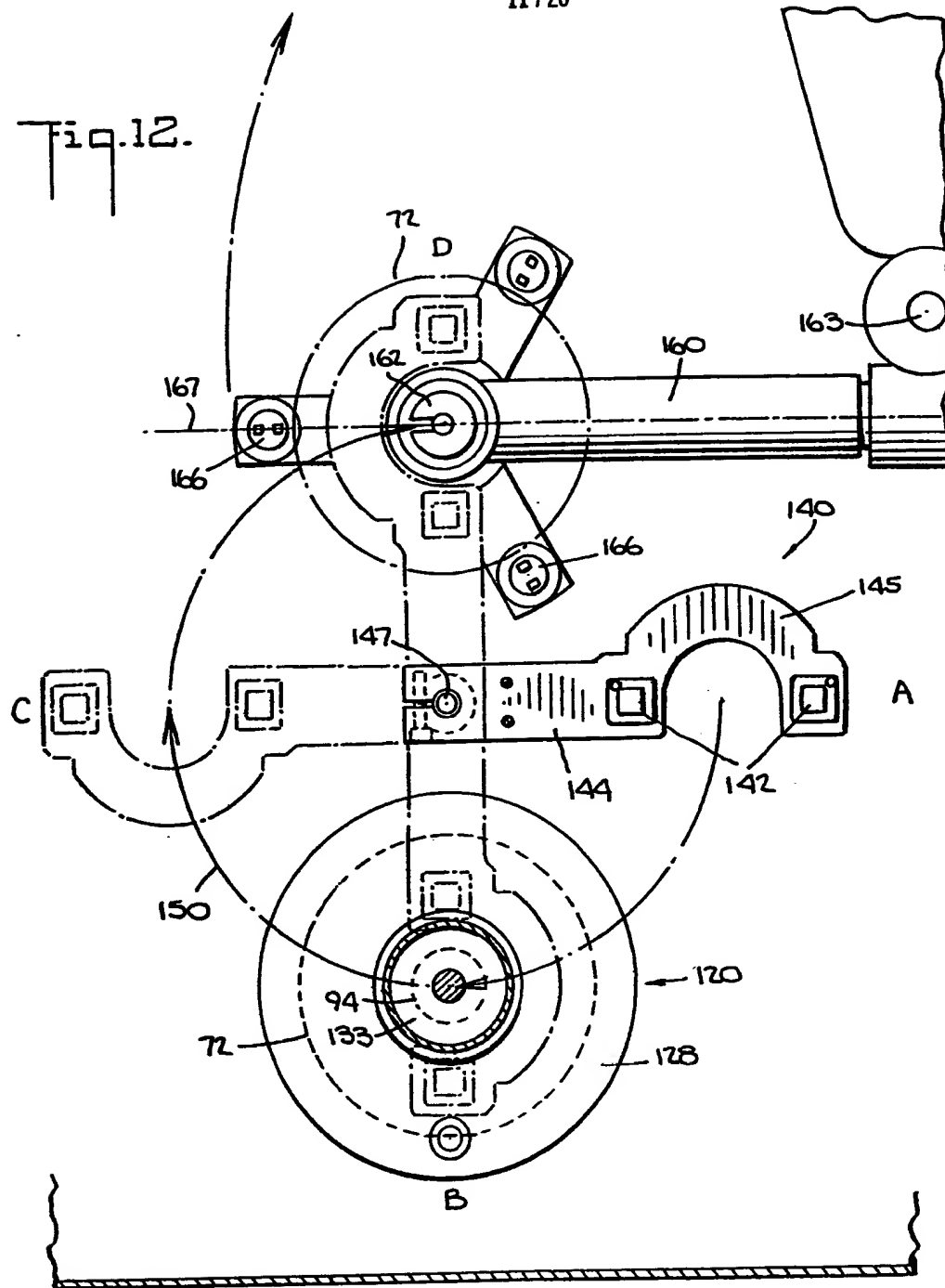
Fig. 9.





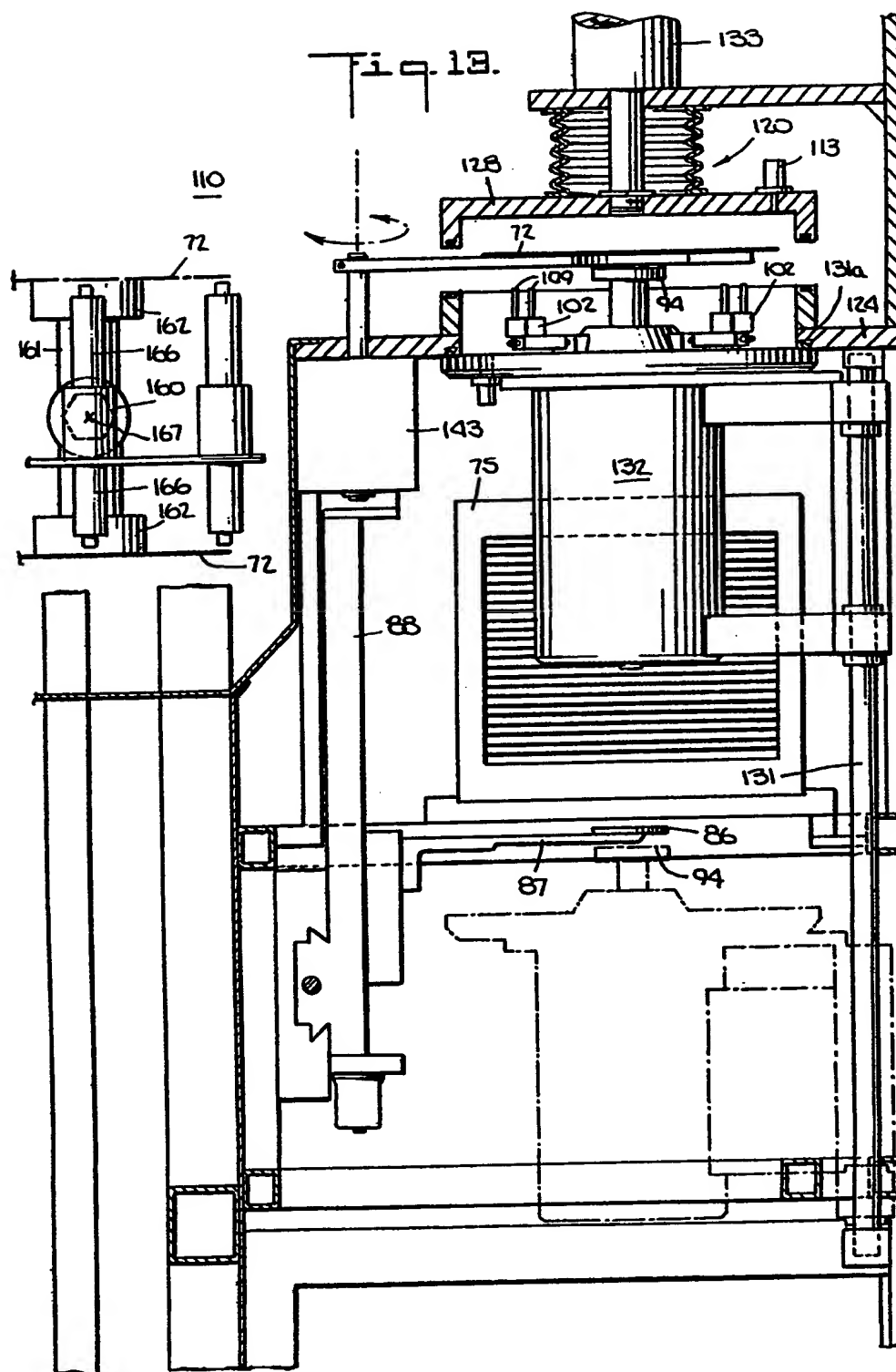
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Fig. 12.

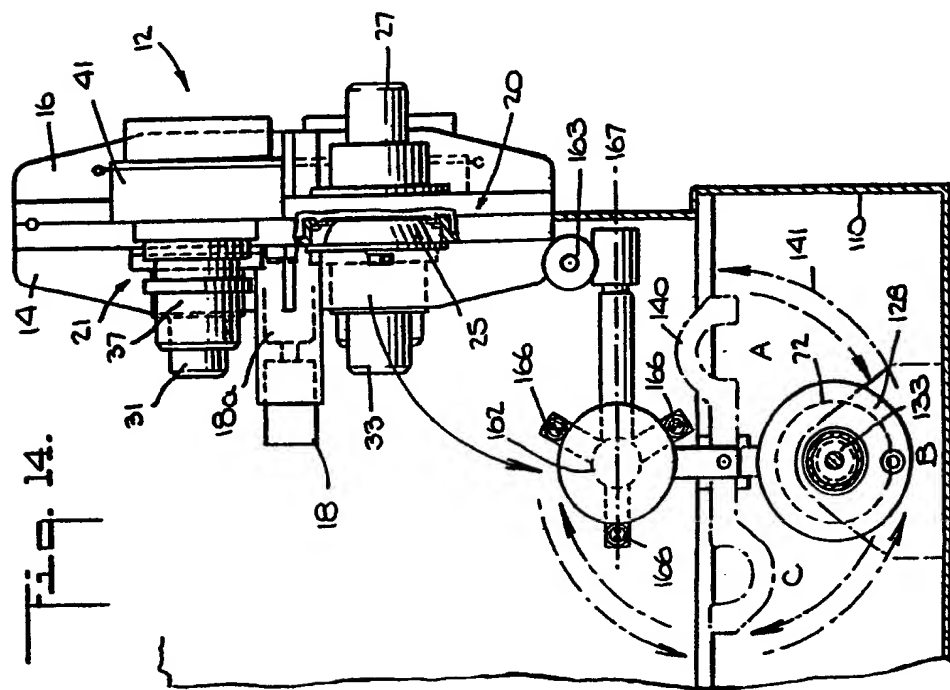
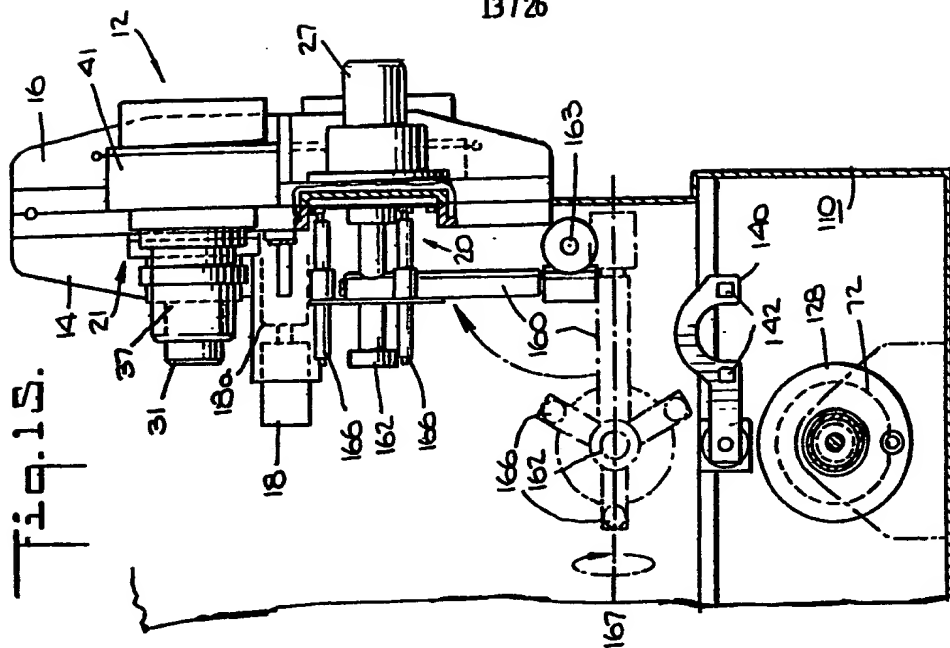


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Fig. 13.

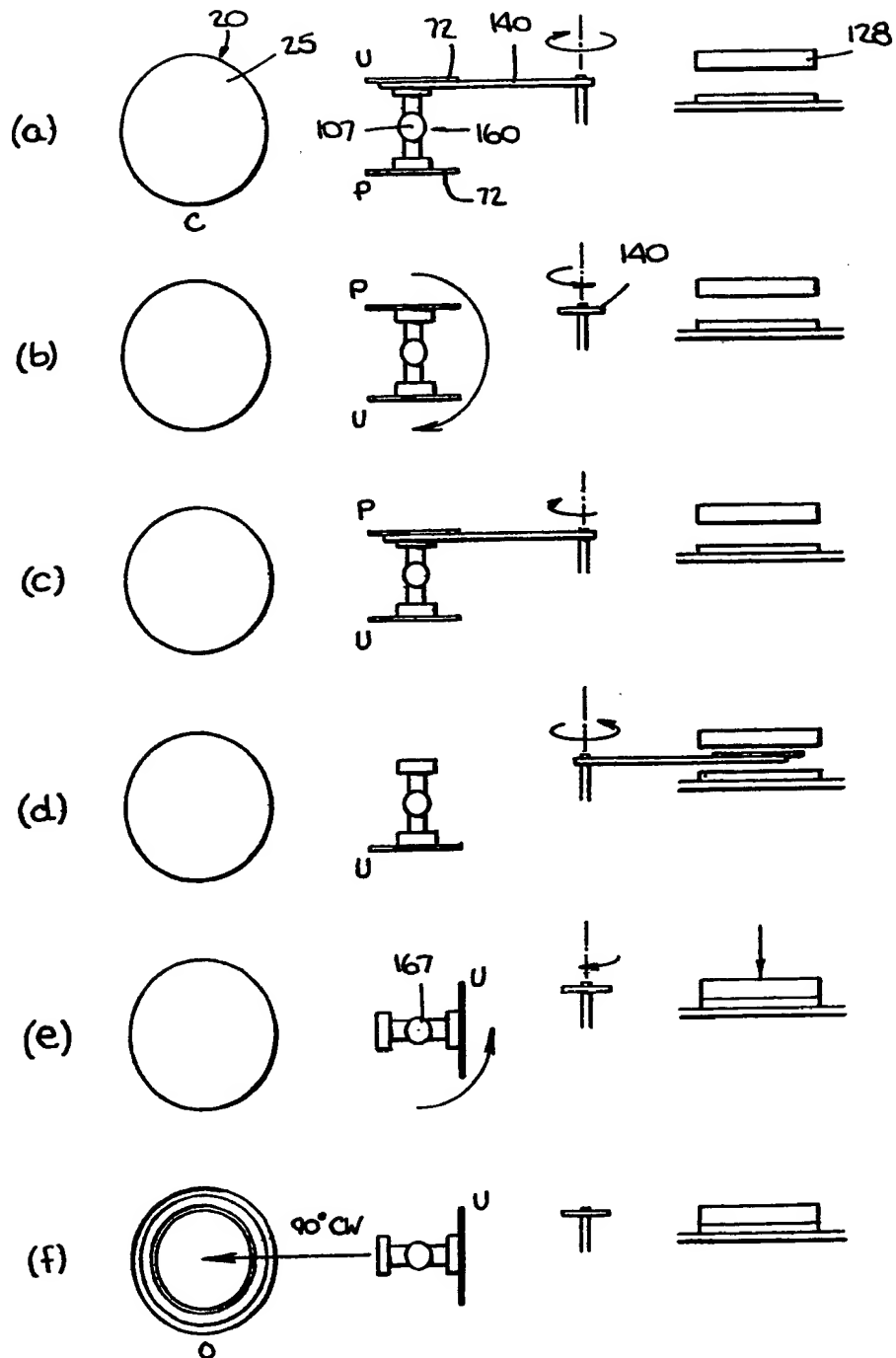


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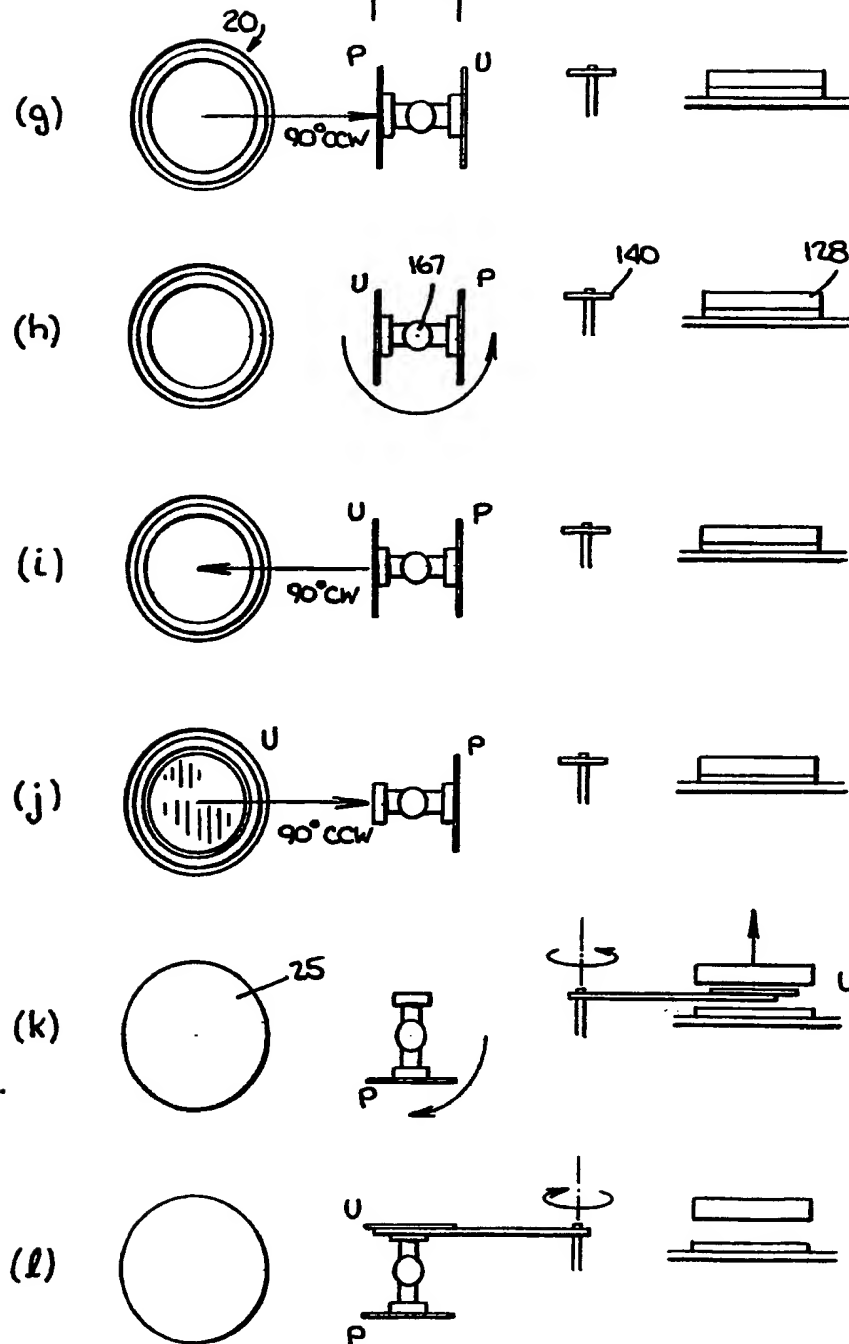
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Fig. 15A.



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Fig. 1SB.



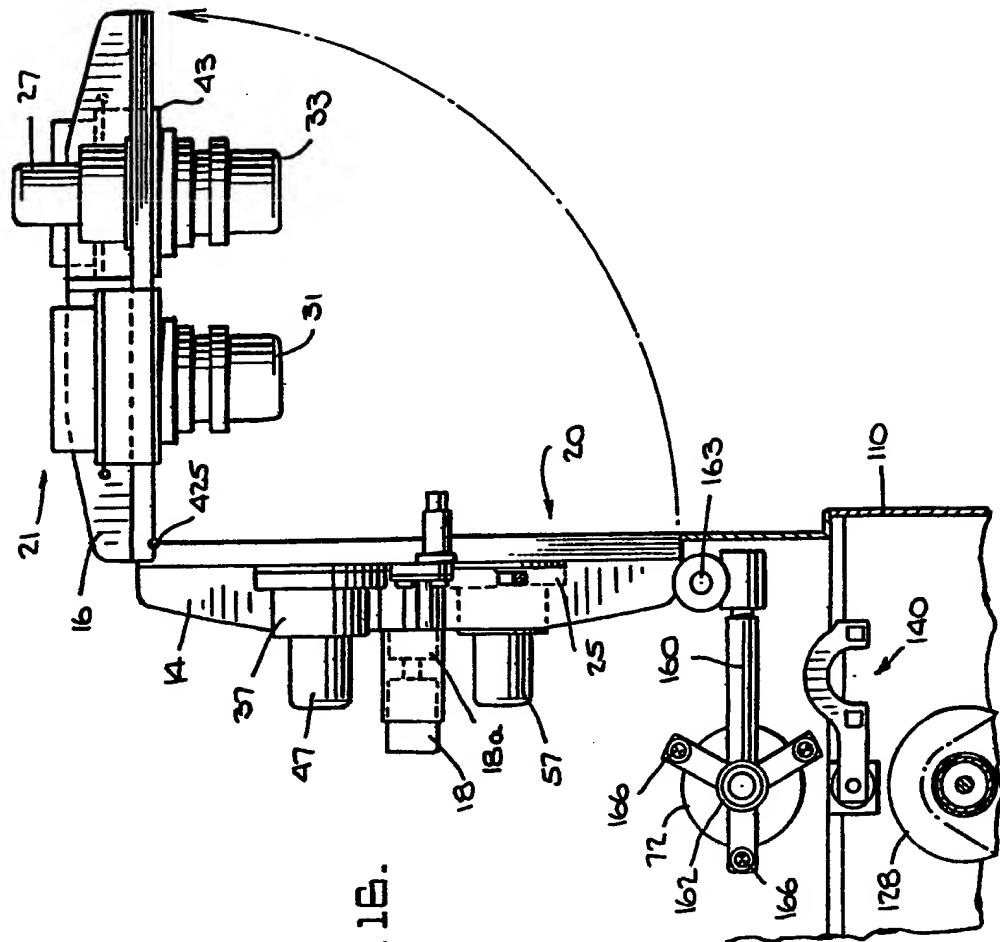


Fig. 1B.

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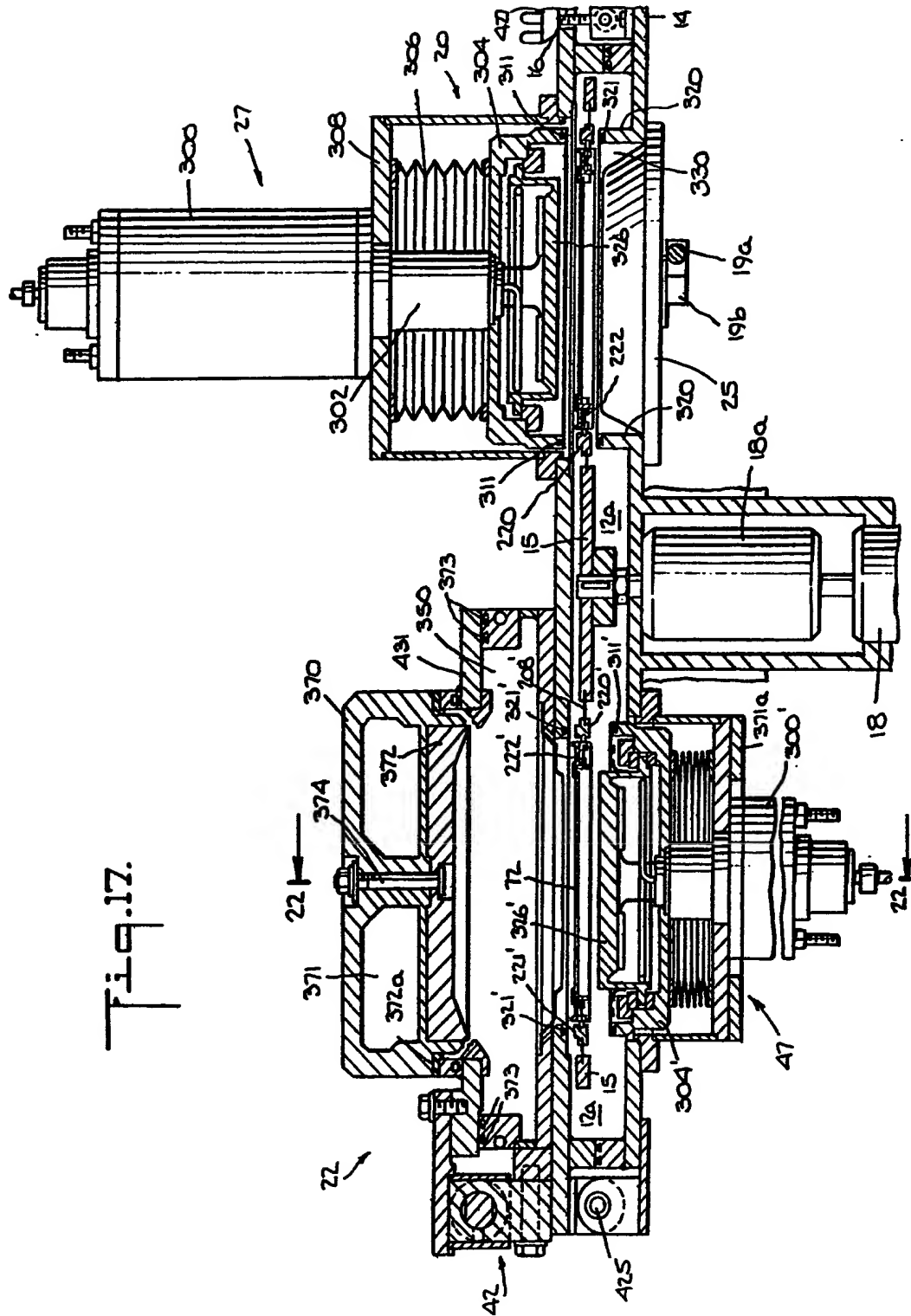
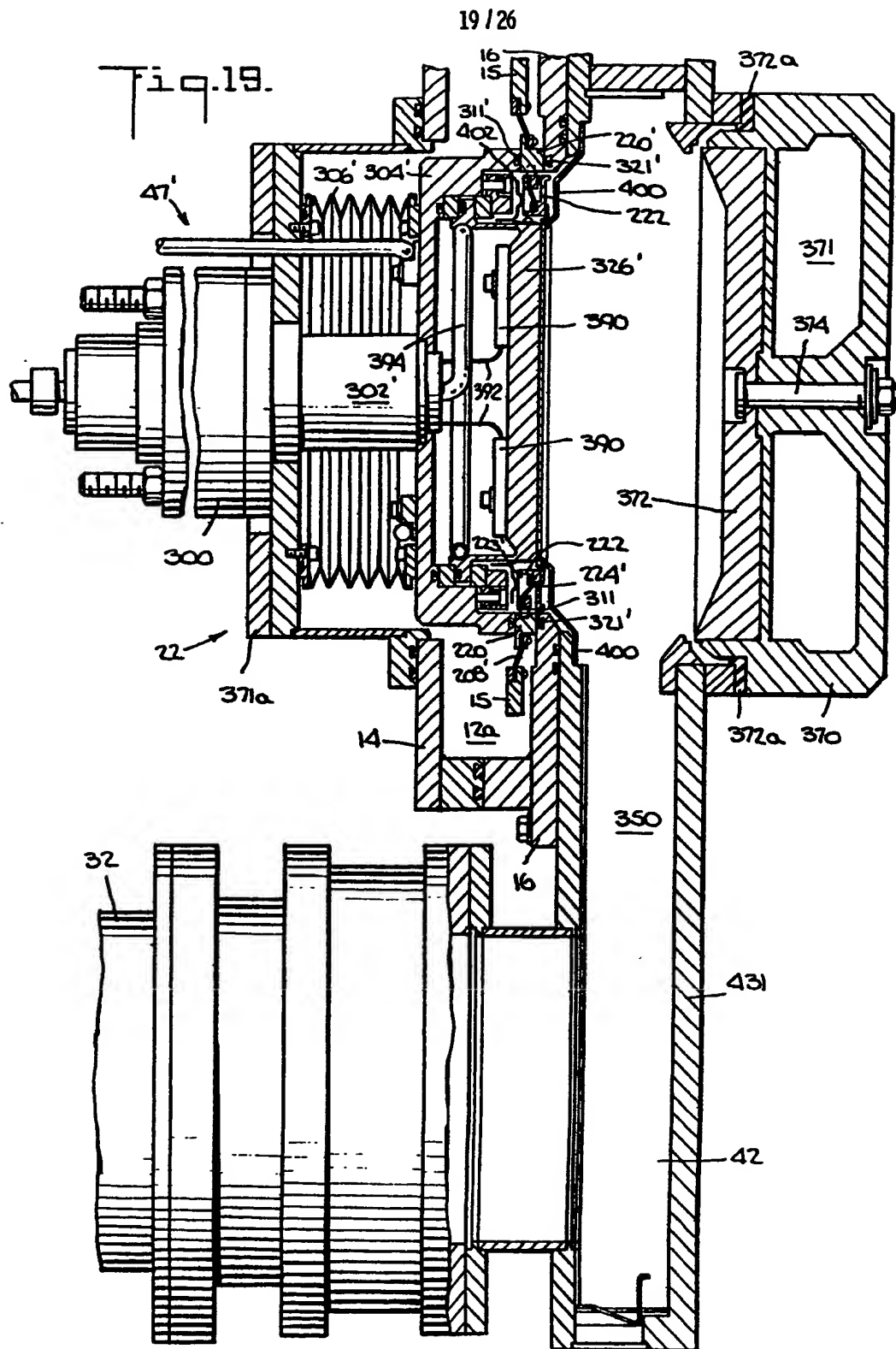


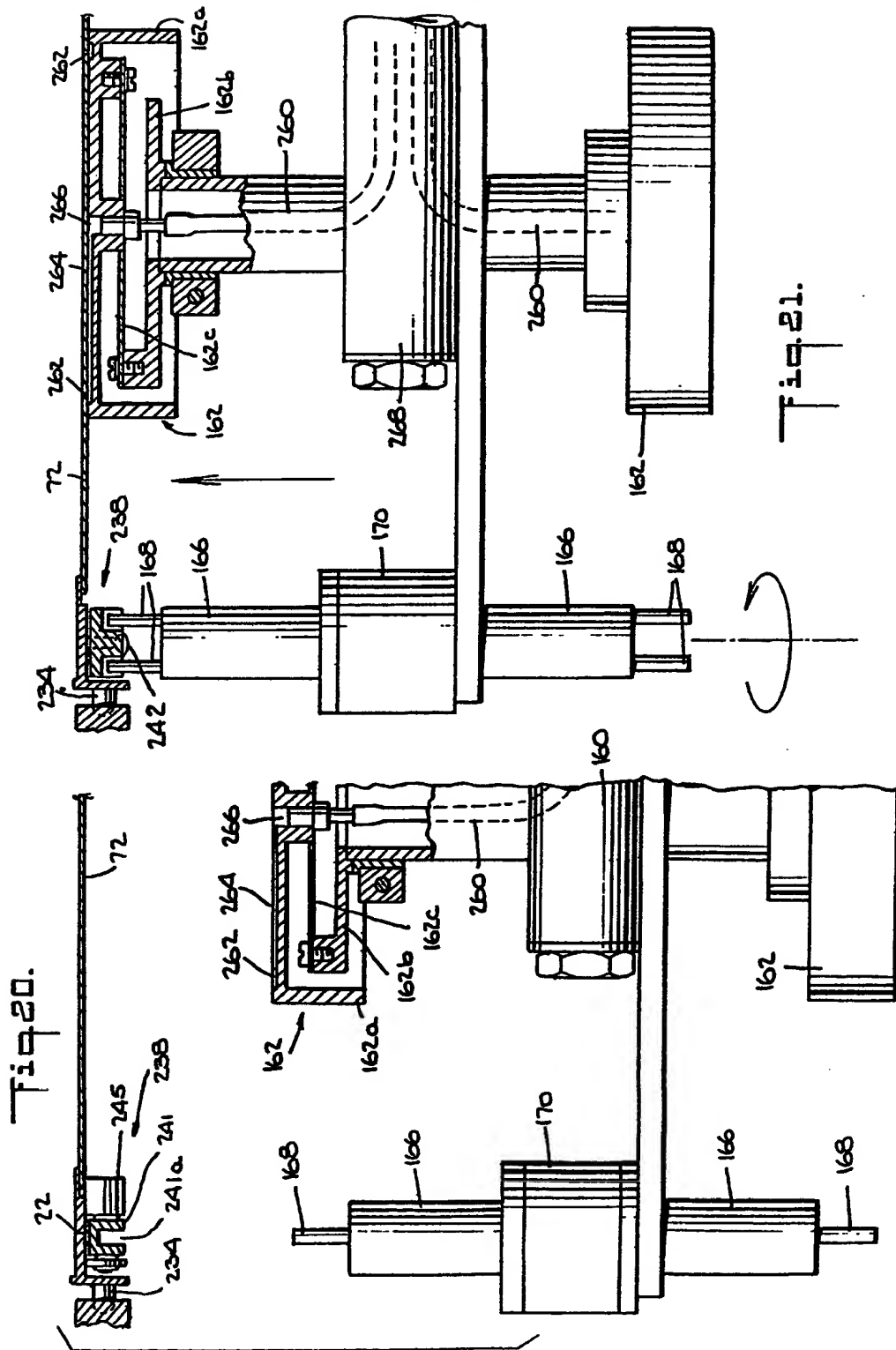
Fig. 17.



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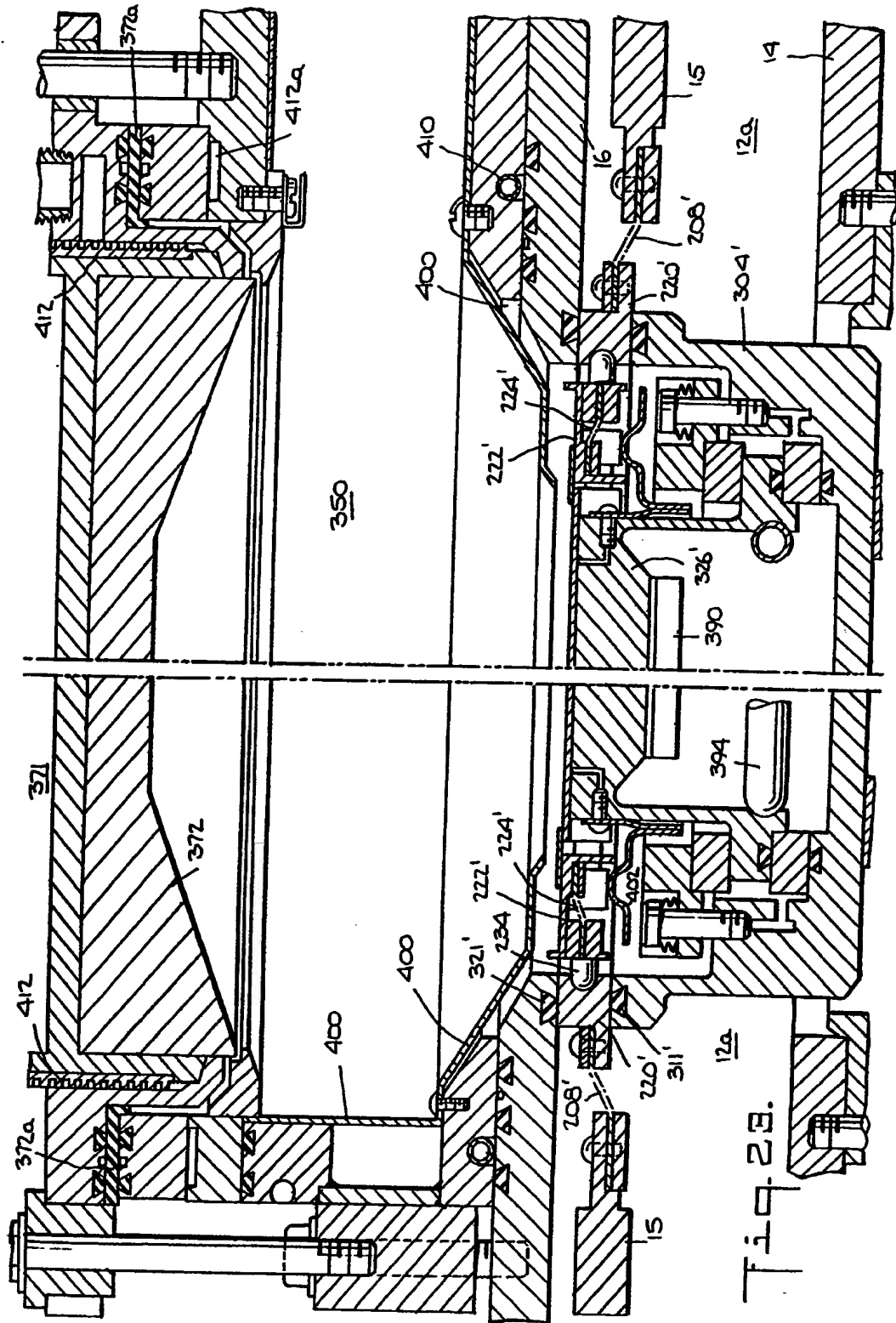
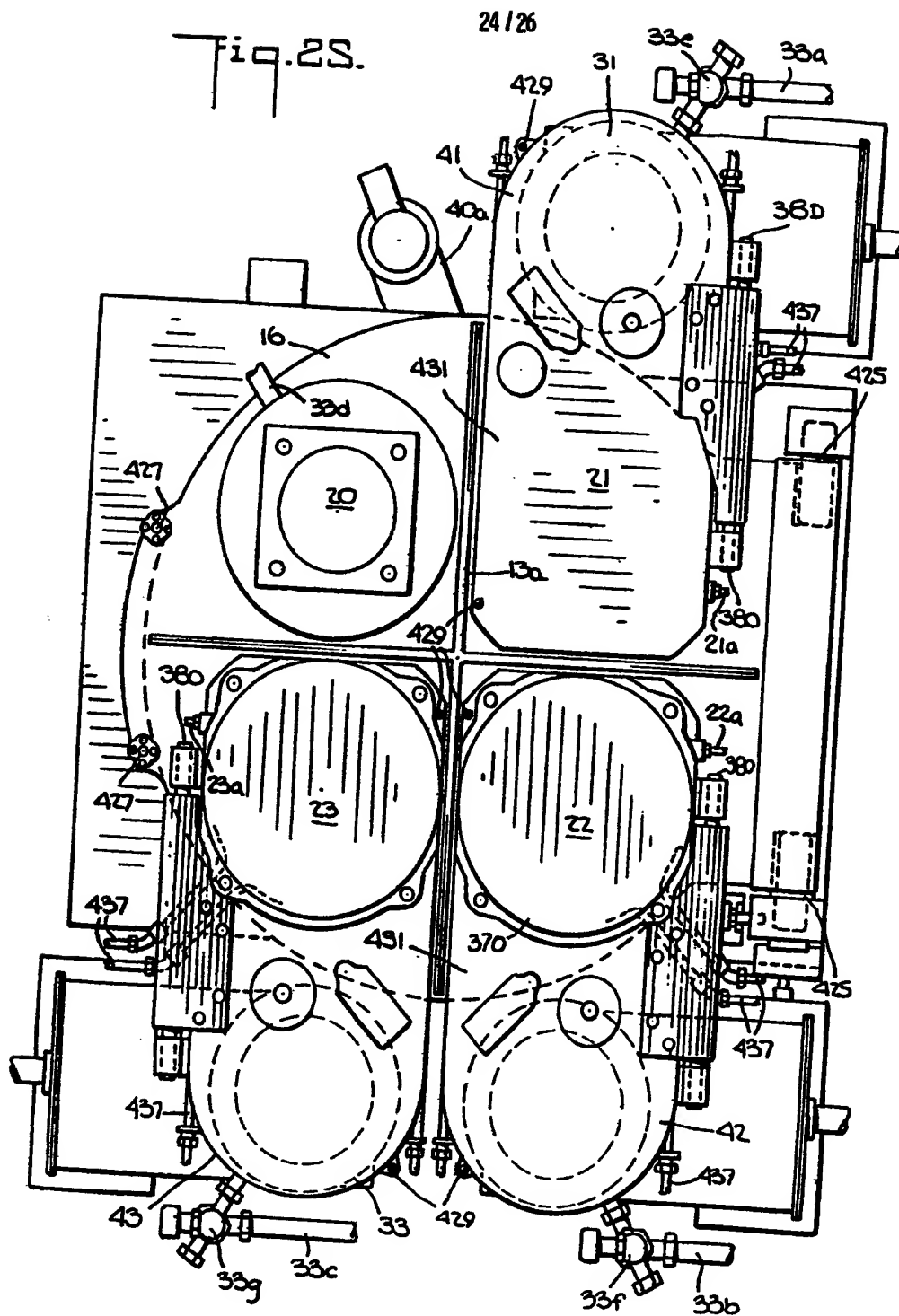


Fig. 23.

Fig. 25.



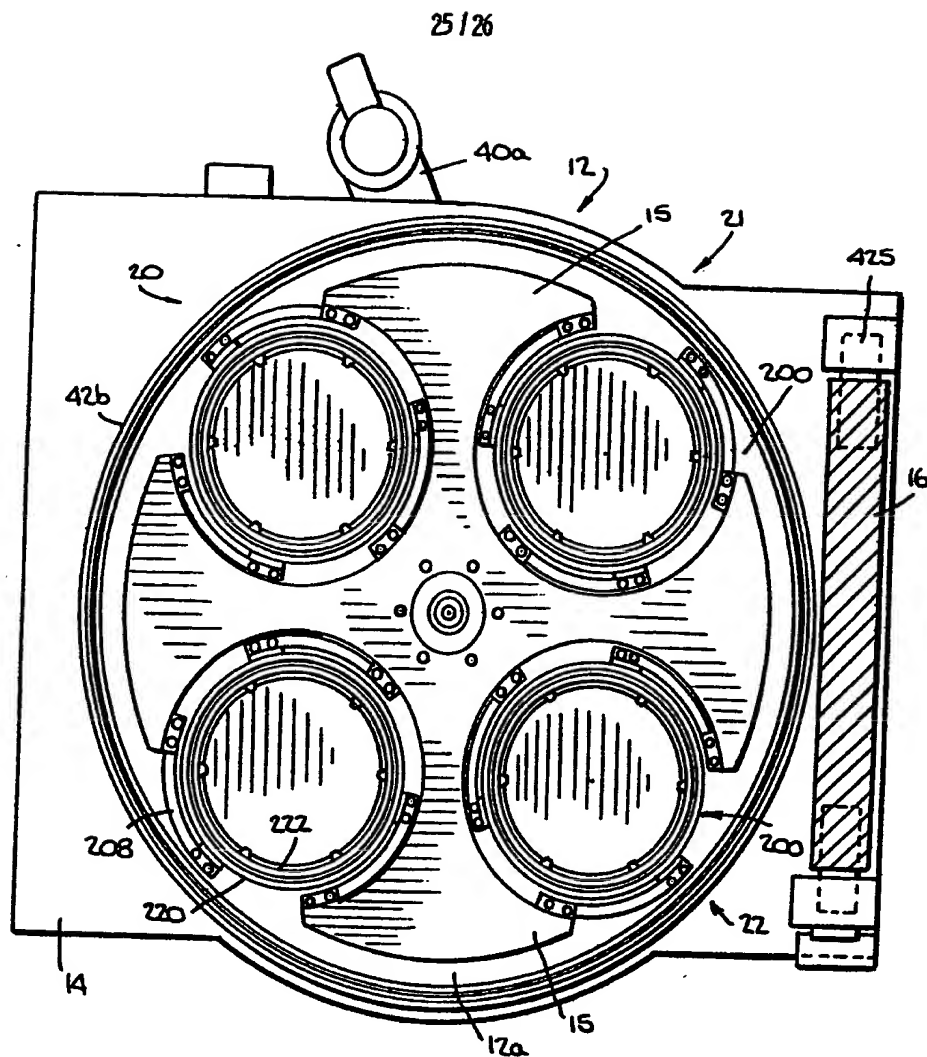


Fig. 26.

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